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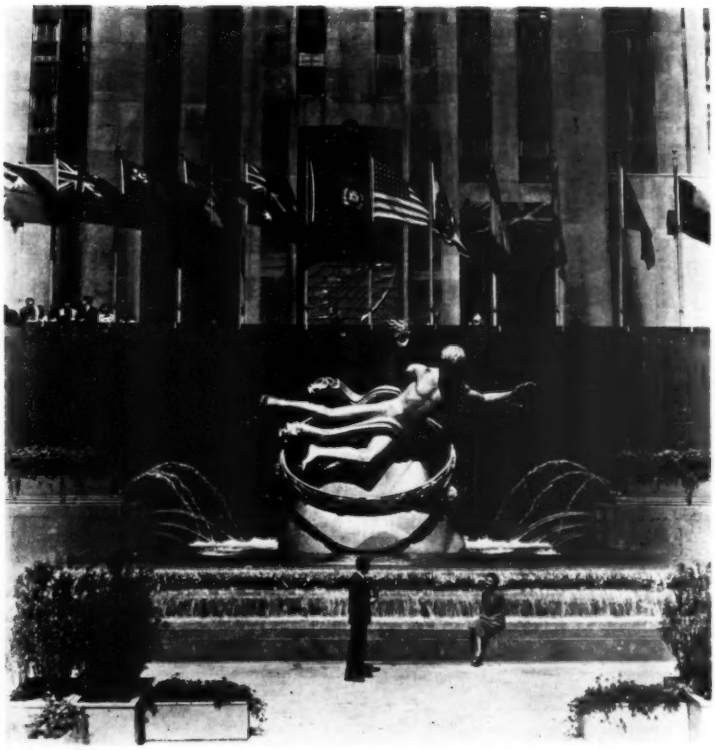
JOURNAL

AIR POLLUTION CONTROL ASSOCIATION

SCIENCE & TECHNOLOGY

Founded 1907



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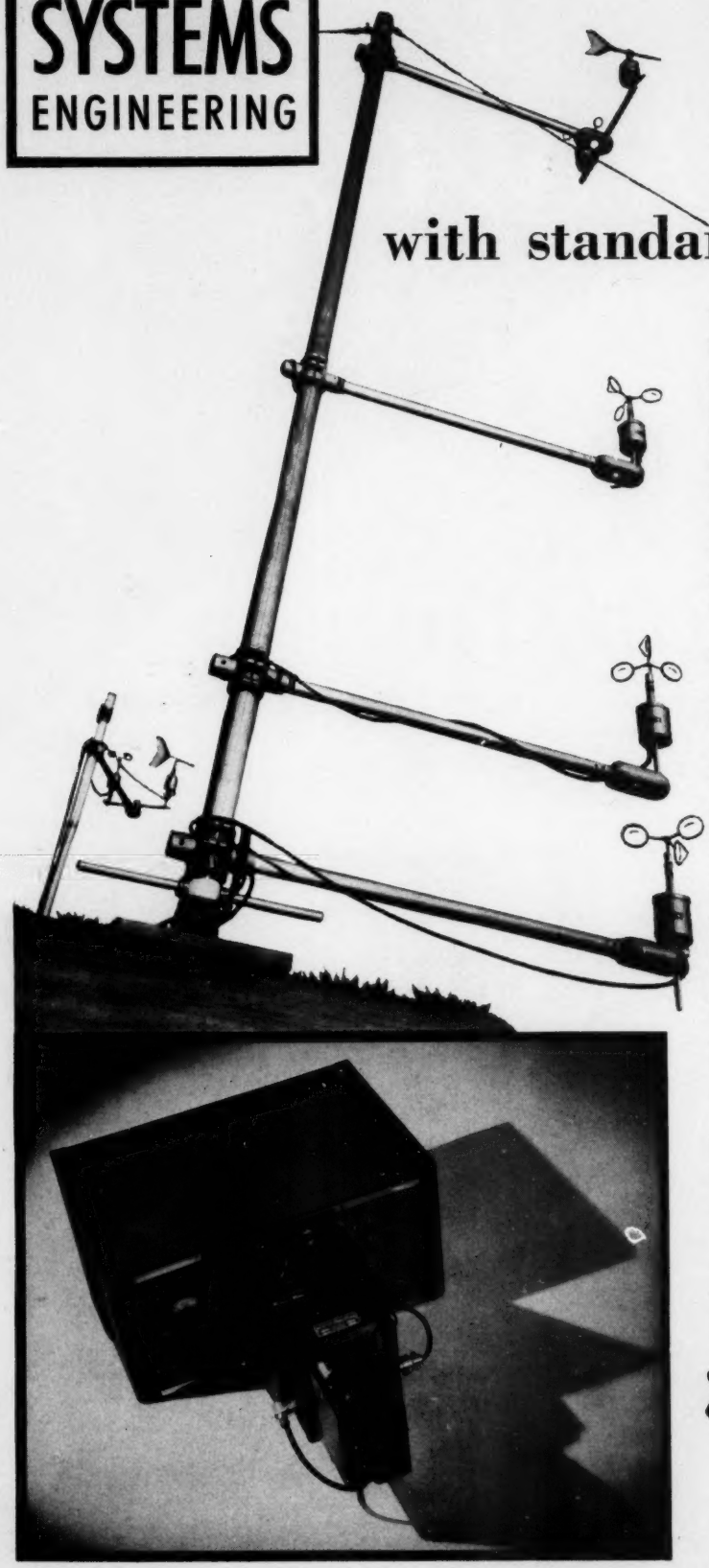

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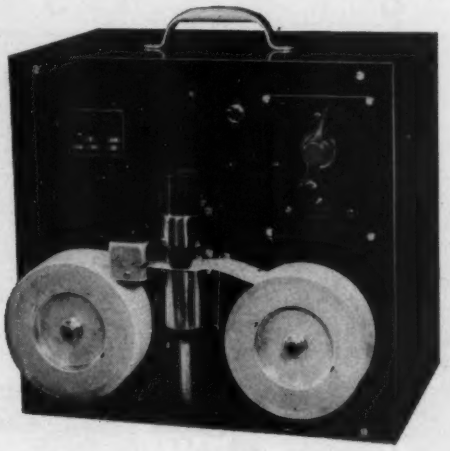

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According to Charles W. Gruber, Air Pollution Control and Heating Engineer, City of Cincinnati, the A.I.S.I. Sampler is also used as an index of soil in the atmosphere, and the results give much valuable information on the build-up and carry-away of the finely divided particles which remain suspended.

Like an increasing number of large cities throughout the country, Cincinnati is conscious of the undesirability of polluted atmosphere. Similarly, an increasing number are depending on the A.I.S.I. Sampler to record for them what contamination is in the atmosphere. They have found, too, that because of its low cost, the A.I.S.I. Sampler can be used in quantity to give complete coverage of the city. And, of course, it operates quietly and continuously 24 hours a day.

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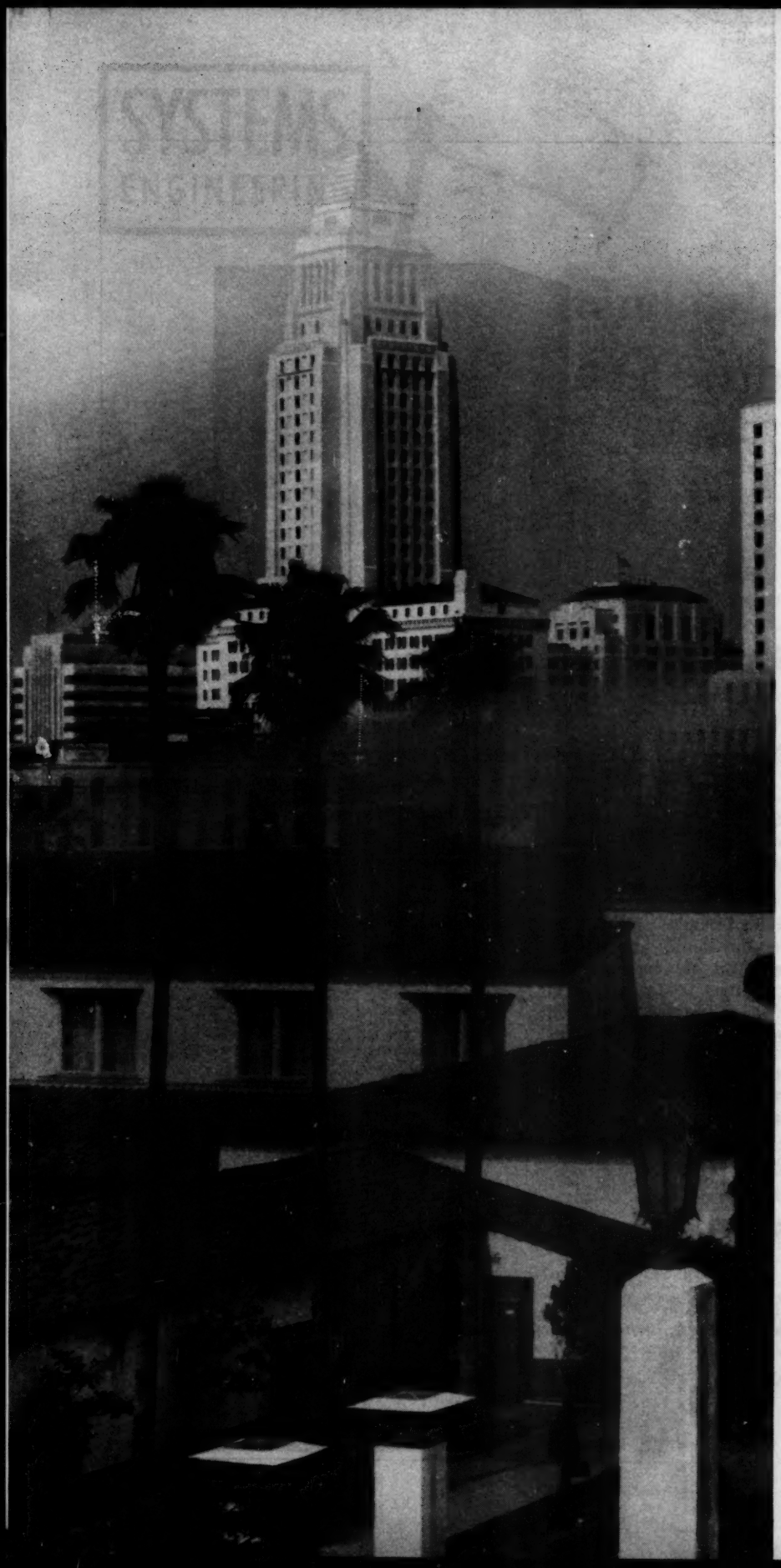

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JOURNAL OF THE
AIR POLLUTION CONTROL
ASSOCIATION

FOUNDED 1907

A Monthly Journal
Devoted to
Air Purification

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The Editor welcomes writers interested in air pollution problems and encourages them to use the pages of this journal for the expression of their opinions. But neither he nor the Association assumes responsibility for the validity of the opinions expressed herein.

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LETTERS to the EDITOR

Fact or Fiction

Dear Editor:

Everybody has opinions regarding air pollution, its causes and cures, since the whole population has had the experience of breathing in an atmosphere that is polluted to some degree. This creates a major problem for workers in the field, with all types of "facts" being circulated by all types of "experts" as the gospel regarding air pollution.

It is therefore of critical importance that the men charged with informing the public on the subject of air pollution be sure of their facts. The article in the January 1961 JOURNAL by Mr. G. A. Lloyd is, in general, an excellent exposition of the current state of research knowledge. There appears in his article, however, some minor points that smack of pure folk-tale origins. They really should be put to rest and not be allowed to continue to circulate, so that one statement of them becomes the authority for their further use.

Smog Forms over Traffic

For instance: (*1*) Mr. Lloyd states that one may notice the "formation of smog clouds over main arteries of traffic in the Los Angeles Basin." While not disputing the fact that automotive traffic is indeed the main culprit here, the fact remains that even a little wind is enough to cause pollution clouds to drift, so that one would not expect to be able to locate such clouds above traffic arteries. Indeed, when viewed from above, as from a mountain or a plane, no such pattern of pollution is evident.

Explorer Noted Smoke

(*2*) The Spanish explorer Cabrillo is always being mentioned as observing smoke in the Los Angeles Basin. Mr. Lloyd does not do violence to history when he mentions this, since he does indicate that the smoke was from Indian fires, and makes no claim that it was in any way like the present day smog of this region. However, when he quotes Richard Henry Dana as having written in his diary in 1834, "I have this day returned from the plaza at Los Angeles and did go to the sick bay with eyes smarting. The pharmacist's mate told me this was not unusual, and the navigator said there was a damned inversion"—he is beginning another folktale.

The fact is that Richard Henry Dana arrived on the Southern California coast in 1835. He served on two ships during the greater part of two years, moving up and down the coast from San Francisco to San Diego. Neither ship was large enough to sport the luxuries of either a pharmacist's mate nor a navigator—nor, for that matter a sick bay.

Mr. Dana had only a summary of his diary upon his return to Boston, the diary itself having been lost. From this summary Dana wrote his "Two Years Before the Mast." No where in this work is any mention made of any air pollution effects as described by Mr. Lloyd.

Credulity boggles at the idea that anyone in the 1830's would be familiar with an inversion, since no atmospheric temperature soundings had yet been made.

Maybe Mr. Lloyd was kidding, but for the sake of the poor befuddled public please let's not try to start a new smog folk story.

Yours sincerely
ERWIN K. KAUPER
434 South San Pedro St.
Los Angeles, Calif.

Durban Cleaner Air Campaign

Dear Editor:

Receipt of your letter of November 30, 1960, is acknowledged with thanks and I

(Continued on p. 192)

SECRETARY'S PAGE

By-Law Amendments Announced

APCA's 17-man Board of Directors, as originally conceived in 1950, was thought to be one which would ideally represent the varied interests in the organization. For this reason, primarily, Article VIII dealing with the election of Directors specifically instructs the Nominating Committee that it shall maintain the proper balance of interest in selecting a slate in accordance with Article VII.

The only mention made in the By-Laws of the Executive Committee is that there shall be one. The Ad Hoc report of the Committee on Committees in 1958 recommended that the Executive Committee should be given broader interim powers in order to facilitate the conduct of the Association's business.

In order to broaden the scope of authority of this Executive Committee, the Board feels that the duties should be defined in the By-Laws. Consequently, the full text of the By-Law Amendment appears on another page of this JOURNAL. It will not be mailed out to the membership. Please study it carefully.

A revision of Section 2, Article IX was initiated. This concerns the succession of Presidency.

Dissolution of Funds

Although APCA has passed the recent re-examination conducted by the Internal Revenue Service, and continues to be classed as a nonprofit organization, the IRS requires that Article VI, Section 2 of the By-Laws be amended to conform to the requirement of its test for a nonprofit association. This By-Law amendment is classed as a "housekeeping" amendment and is self-explanatory. Its text also appears on another page of the JOURNAL.

Public Relations Handbook Available

Joseph H. McGinty, APCA's Public Relations Chairman, has announced that his Committee's Public Relations Handbook is now complete, and available upon request from headquarters. The complex problems involved in a community or a company air pollution control program is the elusive objective covered by the Handbook. It is divided into sections covering the principal channels of communication, and is indexed by the decimal system to make the insertion of periodic additions in logical order as easy as possible.

Membership Reaches 2000 Mark

As forecast in the March JOURNAL, the current membership campaign conducted by Dr. W. L. Faith, membership chairman, has reached a new record. As of March 1, 1961, APCA's total membership reached 2004, including 102 Sustaining, 261 Company, 1641 Individual. This figure reflects all losses up to that date.

Achieving GREATER SENSITIVITY *in* SOURCE SAMPLING *by the* S-N MODIFICATION *to the* HIGH VOLUME *Air* SAMPLER*

MORTON STERLING, Chief, and

SAMUEL NIMLIN, Supervising Inspector, Bureau of Air Pollution Control, Detroit, Mich.

In an effort to obtain data on the extent of contribution of a known or suspected particulate pollution source, it is common practice to operate a high-volume air sampler continuously for a given period of time in the vicinity of the source. After a sufficient number of "runs" and appropriate laboratory analysis, data can be obtained comparing the particulate pollution levels when the wind was coming predominantly from the source, as opposed to the times when the prevailing wind was coming from directions other than the source. Data reduction by this method is greatly dependent upon the reading of a wind recording chart (Fig. 1). Accurate abstractions are obviously tedious and difficult at best. In several problem study situations, the Bureau was hindered in substantiating the need to install control equipment due to less than anticipated "source" versus "background" loading values. It was felt that due to the constantly changing wind direction data comparing "source" and "background" conditions would tend to be minimized. It was then decided that the various effects of fluctuating wind conditions could be alleviated substantially by operating the "source" sampler only during those periods when the wind was blowing within a given sector with relation to the emission point and sampling location. The on-off operation of the sampler was then achieved by designing a cam-actuated microswitch mechanism attached to the wind direction vane. Since it was recognized and previously suggested[1] that wind direction shifts could fluctuate quite rapidly in and out of the pre-selected "source sector" thereby adversely affecting the test results, an electronic variable time relay was designed to dampen the effects of the wind direction changes. A second high-volume air sampler was run during those periods when the source sampler was off by using an inverse switching procedure, and "background" loading conditions were obtained simultaneously during the test. A third high-volume air sampler was run continually during the test, irrespective of wind direction changes, so appropriate comparison of test results could be obtained for both methods.

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22-26, 1960, Cincinnati, Ohio.

Description of Test Apparatus

The test apparatus was housed and/or mounted in or on the Bureau mobile air sampling van (Fig. 2). The mobile station was periodically moved to three locations about the source in a sector of 100° averaging a radius of 1000 feet from the source (Fig. 3).

The basic test apparatus and schematic hook-up of components, as shown in Figs. 4, 5, and 6, are composed of the following major devices:

1. Bendix Frieze Aerovane with Model A. W. Esterline Angus Recorders for wind direction and velocity.
2. Specially designed and fabricated adjustable cam-actuated microswitch mechanism (Fig. 5) used for starting or stopping the "source" "background" samplers. Both 90° and 30° cams were made.
3. Paragon Seven-Day Calendar Dial Automatic Time Switch to control starting and stopping of all test samplers.
4. Zenith automatic switch clock to record elapsed time of one of the directional samplers.
5. Special variable 0–60 second time delay relay to dampen effects of known sensitivity of the Bendix Frieze Aerovane to slight changes in wind direction. It was felt that a time delay in switching from one sampler to the other and vice versa was necessary to prevent undue start-stop action of the directional samplers for short-term changes in

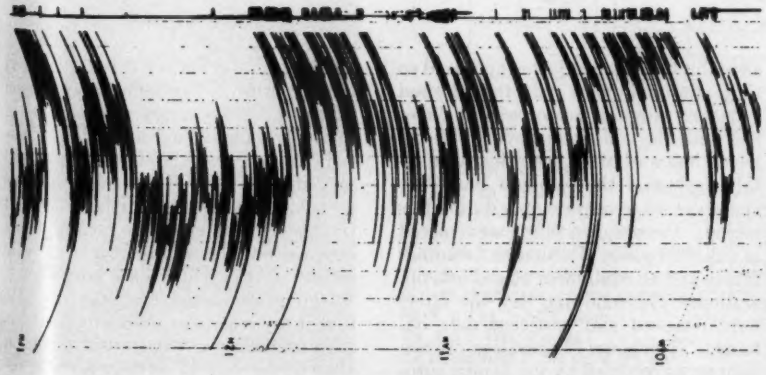

Fig. 1. Wind direction graph.

Fig. 2. Mobile air sampling van.

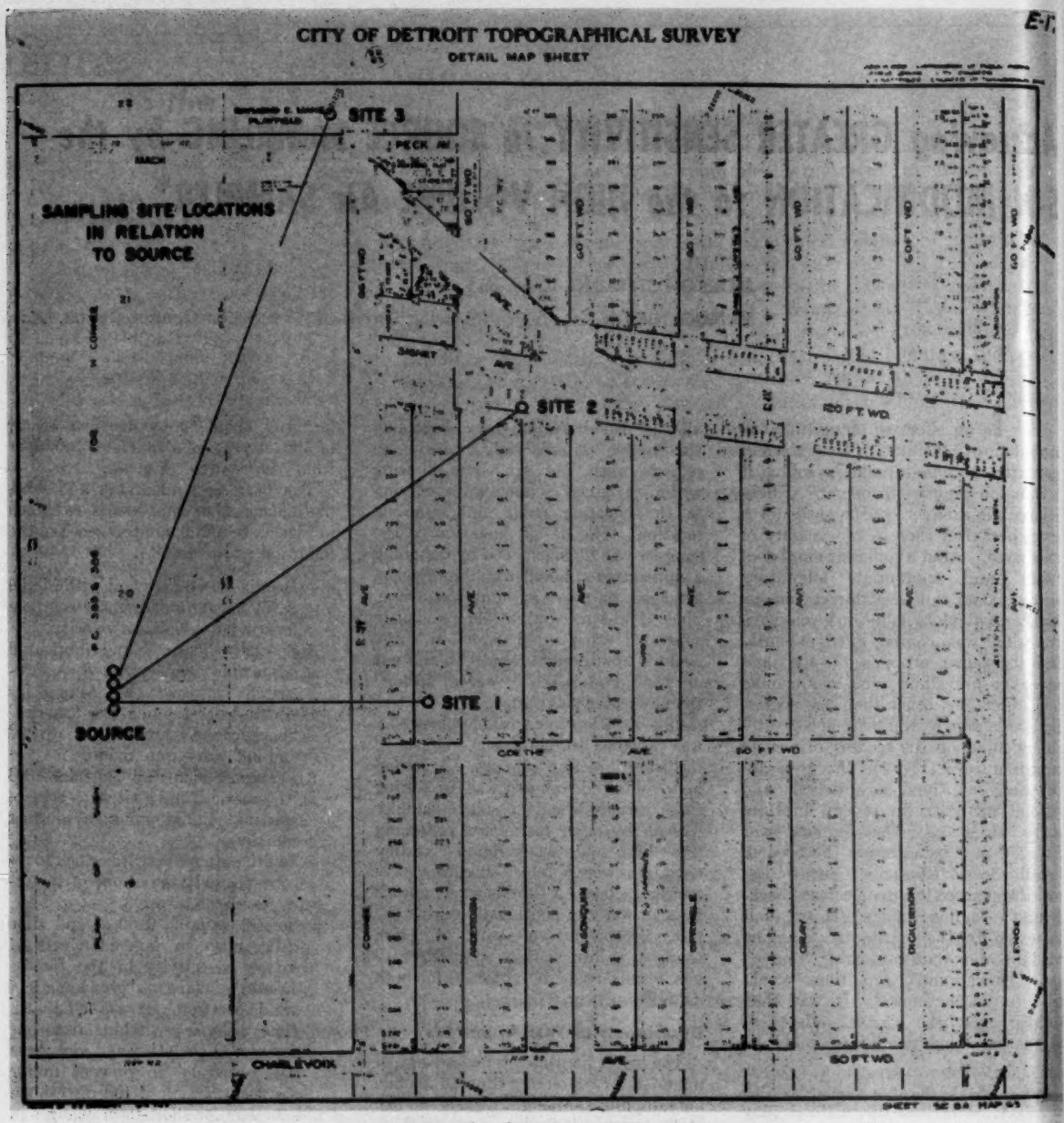

Fig. 3. Sampling site locations in relation to source.

wind direction. The basic electronic circuit is shown in Fig. 7.

6 Three standard Staplex high-volume air samplers fitted with fiberglass filters.

7 Two Variacs to control voltage to the two directional samplers.

Description of Test Procedure

The sampling location was established as several points down wind from the suspected source at the "drop-out" point of the emission, as previously established by visual observation in the immediate area. The cam-microswitch assembly was then adjusted and fixed so that the midpoint of the desired "source" sampling sector was in direct line with the emission source. The believed hours of plant operation were established, and the Paragon seven-day clock was set to operate only during this period. Pre-weighed filters were placed in all samplers, Rotometer readings taken, and all equipment placed into operation. The following day the filters were removed and pertinent data obtained. The hours of operation of each sampler as recorded by the Zenith automatic switch clock and final Rotometer readings at the end of this test period were recorded. The samples were then taken to the laboratory for weighing of total particulates and analysis for percent iron using standard established procedures. The iron analysis was deemed advisable as a further check on the test results, since the facility being sampled was the only known large-scale emitter of this particulate constituent. It should be noted that the variable time delay relay was set for five seconds delay for both in-out and out-in operation after trying various settings for best results.

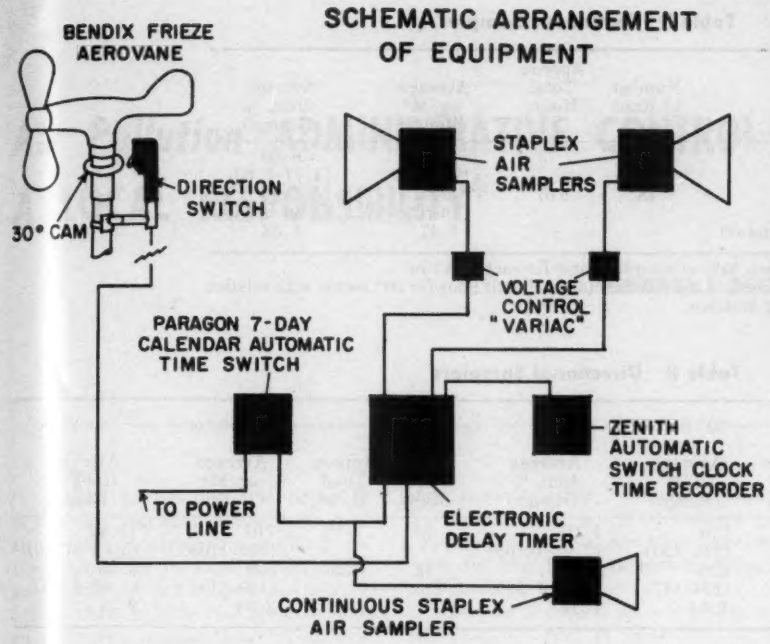

Fig. 4. Schematic arrangement of air sampling equipment.

Fig. 5. Cam-actuated micro-switch mechanism.

Test Data and Results

The test sampling extended over a period of two and a half months (from January 29, 1960, to April 20, 1960), and included 41 separate test runs totaling 900 hr of operation. Eighteen runs were obtained using the 90° cam, and 23 using the 30° cam. The data obtained from four test runs were discarded because of switch failure, high wind damage to samplers, and obvious inaccuracies in analytical test results. All in all, the testing ran smoothly with about a $^3/_4$ man-hour field service time required for each run. The testing apparatus proved to be remarkably dependable.

The test data can be grouped into two main categories—that obtained by use of the two "directional" high volume air samplers, and that obtained by use of the continuous sampler. In both cases the test results are further divided into "source" versus "background" data, as obtained by both techniques cited (see Tables I and II).

Reference to these tables clearly shows the increased sensitivity in air sampling obtained by using the directional samplers, as opposed to data obtained from using a single sampler which is co-related to recorded wind direction data. In the first series of tests a 90° cam was used which yielded slightly higher source/background ratios than the single sampler. This held true for both total particulates and percent iron. Since the noted increase in sensitivity was only moderate, further tests were run with a 30° cam. It can obviously be noted that there was a correspondingly sharp increase in sensitivity due to the more acute angle selected for source sampling. The 30° cam data yielded source/background ratios approximately 96 and 74% greater for total particulates and percent iron respectively, as compared to continuous sampler data. Time did not permit possible further refinement to see whether using an even

Fig. 6. Front view time delay relay.

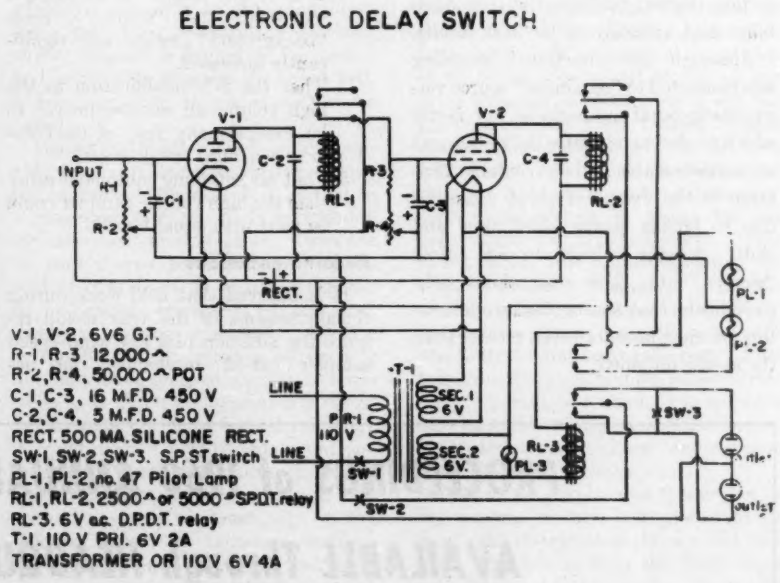

Fig. 7. Electronic circuit of time delay relay.

Table I—Continuous Sampler

Predominant Wind Direction[a]	Number of Runs	Approx Total Hours	Average $\mu g/M^3$ (Range)	Average Iron, % (Range)
Source[b]	7	73	363 (192–694)	6.60 (4.71–7.60)
Background[b]	18	615	247 (79–525)	4.95 (2.46–9.43)
Ratio = Source/Background	—	—	1.47	1.33

[a] Assumed, if more than 50% of sampling time for each test run.
[b] Based upon wind recording data abstracted each half hour for 90° sector with relation to source and sampling location.

Table II—Directional Samplers

	90° Sector				30° Sector			
	Number of Runs	Approx Total Hours	Average $\mu g/M^3$ (Range)	Average Iron, % (Range)	Number of Runs	Approx Total Hours	Average $\mu g/M^3$ (Range)	Average Iron, % (Range)
Source Sampler	9	40	370 (214–430)	7.10 (2.92–10.05)	13	19	710 (390–1705)	12.82 (3.74–37.20)
Background Sampler	18	400	226 (134–447)	4.62 (2.71–7.59)	18	256	259 (100–613)	5.55 (2.56–9.90)
Ratio = Source/Background			1.64	1.54			2.88	2.31

"narrower" sector than 30° would yield more sensitive results. It should be noted, however, that as the source sampler sector was decreased (90° to 30°) a reduction in total "source" sampling time was obtained. It could be that too "narrow" a sector would not permit sufficient source sampling time for valid comparison to "background" sampling. It was encouraging to note that the test data show a relatively minor variation in "background" results for total particulates and percent iron, irrespective of test technique employed. This, to a certain degree, confirms the reproducibility and accuracy of the test results.

Although the directional sampling was instituted to "maximize" source versus background comparisons, one factor which tended to minimize the results was an uncontrollable and unavoidable variation in the extent of plant emissions due to breaks during lunch time and shift changes which would affect "source" data. This is mentioned only to indicate that source/background ratios are most probably even greater than the results obtained.

Conclusions

The test results are believed to support the following conclusions:

1. That the S-N modification to the high volume air sampler will significantly increase the sensitivity of "source" versus "background" air sampling data.
2. That the required sampling time to achieve valid results can be greatly shortened and show truer "source" versus "background" ratios than by using the continuous sampling method when correlated with wind direction data.
3. That as the "source" sector angle is narrowed, the "source" versus "background" ratios are significantly increased.
4. That the S-N modification to the high volume air sampler proved to be exceptionally free of electrical or mechanical weaknesses.
5. That air sampling equipment other than the high volume sampler could be used with equal benefits.

Recommendations

It is believed that field work during certain seasons of the year would require the addition of a low wind speed sampler cut-off mechanism for accuracy. Such equipment is presently being designed and fabricated for cut-off at three mph. Cut-off speeds will be made variable in the event a different speed is deemed advisable. It should be noted, however, that essentially no such problems were encountered during the test runs cited herein, since the average wind speed amounted to approximately 11 mph with wind speeds below three mph for only three percent of the field sampling time.

Further work should be undertaken to determine the most optimum angle for the sampler cam.

Acknowledgments

Appreciation is extended to Stanley Lapa, Electrical Inspector, Bureau of Electrical Engineering, City of Detroit, and Wallace Walker, Air Pollution Inspector, Bureau of Air Pollution Control, City of Detroit, for their invaluable assistance in designing the circuitry and fabricating the equipment for the cam-actuated switching mechanism and time delay relay.

REFERENCE

1. William A. Munroe, "Automatic Instrumentation for Air Pollution Monitoring," *Ind. Hyg. Quart.* (Sept. 1956).

PROCEEDINGS of 1960 ANNUAL MEETING

AVAILABLE Through HEADQUARTERS

Air Pollution ADMINISTRATIVE CONTROL— A LOCAL RESPONSIBILITY*

GEORGE E. BEST, Manufacturing Chemists' Association, Inc., Washington, D. C.

The purpose of this paper is to persuade you that administration of air pollution control, as a public function, should be in local hands. The more I learn of this subject, the more I believe there is little real disagreement on this score among those of an objective view. So I do not feel that I am tackling a difficult task at all.

However, it is apparent that considerable confusion and misunderstanding have arisen about expressed opinions because the actual intent has not always been clear. For example, enthusiastic proponents of local control at times may have given the impression that there should be no attention or activity on air pollution whatsoever at the state or federal level. I doubt that this was ever really meant, and not much reflection is needed to know that such would be unrealistic, even prior to the well established federal and state activities as they exist today which are making major contributions to the various technical aspects of measuring and assessing airborne substances.

I think there has also been insufficient qualification of the word "local" in this connection. In many instances, undoubtedly, it has been taken to mean individual counties or cities or towns as defined by their respective incorporated boundaries. In my opinion this is too narrow a definition. Just as excessive air contamination from a particular group of emission sources rarely affects an entire state, it is seldom so confined that only a single small political jurisdiction is involved. Why should this latter fact not lead to the idea that regulation and policing should be in the hands of higher level authorities, even the federal level, inasmuch as state or international border areas are not uncommonly involved? Leaving unanswered for the moment what I consider to be a logical concept of "local," let us examine this question from the standpoint of people, places, and funds.

Since air pollution as a problem is indisputably local in character, with no two situations alike, it calls for qualified people on the local scene to deal with it, no matter where the authority is vested. People operating under distant management with no direct accountability to the local populace simply cannot avoid being less sensitive to the local situation, and less inclined to recognize its singularity. This is human nature at play and has little to do with experience or competence or conscientious dedication of the individual. This is the basis, surely, for our founding fathers' general principle that to the maximum possible extent people should govern their own affairs. Stated another way, it is only logical that local authorities can be more effective, especially in obtaining progress through co-operation—without which progress is bound to be slow—and better able to gauge the speed with which corrective measures should be paced.

Higher authorities have an inescapable handicap reflected by the following example. Operator A is located in a congested complex closely surrounded by extensive housing areas; Operator B, very similar to A in type and extent of operations, is virtually isolated in a location relatively remote from dwellings among essentially desolate surroundings. In virtually all cases it does not make sense to apply the restrictions to B which are appropriate for A, yet to a state-wide or federal authority A could make a plea of unfair and discrimatory treatment unless the same regulations apply to both, and the authority would be constantly on the defense against its necessary employment of arbitrary judgment and decision. Separate local authorities are not handicapped in this way, and there should thus be fewer complications in full and proper use of the atmosphere as a natural dispersant.

A deeper significance is revealed from the standpoint of locating new operations, which industry is faced with daily in our rapidly expanding economy and mushrooming population. Air pollution has been added to the numerous considerations to be taken into account. The prospect of unnecessarily restrictive regulations can be a deciding factor, with resultant effect on community income and growth. Competitive enterprise should have the widest latitude possible to capitalize on ingenious utilization of natural resources, including the atmosphere, consistent with safe and proper public interest.

It is perhaps just as well that our senses have become somewhat numbed in money matters by the accustomed references to millions and billions of dollars, for the economic burden of air pollution is unavoidably high—perhaps currently in the order of magnitude of $5 billion, equivalent to 1% of our gross national product. As a specific example, it has been estimated that nearly $400 million will have been spent when the Los Angeles smog problem is brought under satisfactory control, amounting to about $80 for each inhabitant of the County. This is not to cry out against spending for what is needed. Rather it is to emphasize guarding against unnecessary restrictions which can add very substantially to the aggregate cost. Further, from the standpoint of administrating air pollution control, it is to point out that the pyramiding organization essential to high level enforcement authority adds to the expense.

Not wanting to belabor this aspect of my remarks unduly, two quotations on local administrative authority will suffice. The first is from the First Biennial Report of the Oregon State Air

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

Pollution Authority (1954):

> "Field investigations of...complaints have shown that effective air control within a city would involve the regulation of a large number of pollution sources such as industrial plants, space heating in apartments, emissions from commercial establishments, and contributions from individual households which could not be regulated efficiently by a state agency. In order to encourage air pollution control within Oregon cities the Authority has adopted the following policy:
>
> *a* To preserve and encourage local autonomy on matters of air pollution control to the extent that cities would be expected to carry on local programs for air pollution control with such technical assistance and advice from the Air Pollution Authority as may be necessary.
>
> *b* Co-operate with cities in the furtherance of local air pollution control programs.
>
> *c* Collect and disseminate information to cities on the prevention and control of air pollution."

Several years ago Dr. H. H. Schrenk, then Research Director of the Industrial Hygiene Foundation, had this to say (5th MCA Semi-Annual Meeting):

> "Local areas can look to their state organizations for guidance and technical assistance, which in turn can seek aid from the federal level.... The most important contribution at the federal level...will be to conduct, sponsor, and co-ordinate research, with particular emphasis on the health aspects."

I concur in these views, which are consistent with the principles espoused by the Manufacturing Chemists' Association in its publication, "A Rational Approach to Air Pollution Legislation."

There evolves, then, the picture of co-operative approach with each level of government taking care of what is logically in its province and for which, accordingly, its facilities should be best suited. Thus it is quite the opposite of attempting to delegate all of the pertinent functions to one governmental level.

Federal efforts, then, would be along lines of common interest and concern across the country, the information being sought to have wide applicability. This bespeaks research—in the development of apparatus and techniques for identifying and quantitating air-borne substances, and assaying any effects they elicit in people, animals, or property. At this point on the subject of publicity on air pollution in relation to public health, I was most favorably impressed at the time of the recent New Orleans Air Pollution Symposium (on current research) with the absence of headlines or press stories which could be readily mistakenly interpreted and generate unwarranted fear among an unknowing public. As a former research man myself I realize the advantage of open discussion among research workers in suggesting and testing hypotheses, and I subscribe to the public's right to know the facts. But preliminary opinions, conjectures, and untested hypotheses are not necessarily facts, and I believe researchers should feel a strong obligation to do all in their power to keep the public's focus on their work in proper perspective.

The same applies with equal, or perhaps greater, force to outside investigation and survey. Indictment by advance publicity can be quite devastating, even though those responsible are completely honorable and innocent of any purpose other than to do their job thoroughly and well.

So far as public health is concerned, one can visualize the Public Health Service's primary responsibility for air quality standards significant from the health standpoint, analogous to the long-standing USPHS Standards for Drinking Water, in which specific tolerance limits are given. In the air field as well there seems to be a growing acceptance of the concept that there are noninjurious threshold limits having general applicability.

The role of state government is appropriately that of providing guidance and assistance to local control authorities. Economies in the technical sphere can thus be realized, since specialists and the more complex items of equipment too costly for all but large local areas could better be made available. Advisory committees, composed of representatives from various public and private interests within the state, can help in matters of general policy and in co-ordinating the programs of those they represent to achieve solid progress. The force of such collective representation also can effectively be brought to bear on areas that may tend to lag behind in bringing about needed corrective action.

Let us proceed from here, then, with presumed agreement that the control authority, specifically, the power to set up regulations and require compliance with them, should be at the local level. It takes no imagination to realize that a conscientious and progressive town or city, or even county, could continue to suffer if its immediate neighbor failed to do its proper job, too. (The wind just won't blow in one direction all the time!) The only mutually satisfactory approach is to get together on the problem. Here terminology varies. The MCA publication referred to before suggests the creation of an air pollution "zone," in some quarters this may lack appeal because "zoning" has come to have a specific connotation quite different than the purpose here in view. "Region," "area," or "district" are possibilities; in the water pollution control field there are a number of "compacts" which accomplish the same end. The name is unimportant. The idea is valid, namely, for a single control authority to be established within an area affected by a common group of air pollution sources, having jurisdiction over the entire area. Geographically some areas of common pollution are extensive, others are small; some cross state lines or international boundaries. Legislatively, this calls for enabling laws and statutes, providing for delegation of authority in this way.

As a practical matter the unique approach to each individual pollution area problem must be preserved and encouraged if progress is to be made with fairness to all. Placing this responsibility within the affected area is the best guarantee that it shall be so.

Welcome New Members

Company Memberships (Local)

Johns-Manville Fiber Glass, Inc.
Corona, Calif.

Riverside Cement Company
Riverside, Calif.

Southwest Steel Rolling Mills
Los Angeles, Calif.

Individual Memberships

Adams, Charles E.
Pensacola, Fla.

Anderegg, F. C.
St. Paul, Minn.

André, Wurgler
Quebec, P. O. Quebec, Canada

Anselin, Fernand M.
Brussels, Belgium

Bartholomew, W. Erle
Sheffield Lake, Ohio

Belcher, A. L.
St. Louis, Mo.

Borgwardt, Robert H.
Lakeland, Fla.

Brown, Astor
Louisville, Ky.

Chessher, H. B.
Reno, Nev.

Chute, A. E.
Los Angeles, Calif.

Clarke, Samuel M.
Chicago, Ill.

Courtney, Francis E., Jr.
Atlanta, Ga.

Crancer, Ray A.
Montague, Mich.

Delaney, George J.
New York, N. Y.

Dworek, Richard
Harrisburg, Pa.

Edmunds, Henry E.
Dearborn, Mich.

Emmer, Erwin A.
Cincinnati, Ohio

Farley, Derrik Gordon
Bradford, England

Faust, W. A.
Tonawanda, N. Y.

Fickett, R. E.
Berlin, N. H.

Flatt, Joseph
Dayton, Ohio

(Continued on p. 174)

Air POLLUTION PROBLEMS *of the* FOUNDRY *Industry*

Informative Report No. 1

Committee TI-7 Ferrous Foundries
HERBERT J. WEBER, Chairman

In the eyes of the public the foundry industry is a potential source of air pollution but when it is compared with many other basic industries, one finds that the equipment needed to reduce pollution of the air by contaminants from the foundry is for the most part in common use. Collectors that reduce particulate emissions from grinding, cleaning, material handling, shakeouts, etc., have been in use for years by most foundries.

It is recommended that foundrymen study and understand the effects that air pollution can cause on man, animals, vegetation, and property as well as on the surrounding areas.

Effects of Air Pollutants on Man

In only a few isolated cases such as the Meuse Valley of Belgium in 1930, Donora, Pennsylvania, in 1948, and more recently the London fog, has air pollution been blamed for sickness and deaths among people. In many cases the victims were already afflicted with a respiratory disease or other physiological complications. Rare indeed is the combination of topographical and meteorological conditions which permit the accumulation of sufficient pollution to produce an acute effect.

The systemic effect on man of more normally encountered types of air pollution from ferrous foundries has not been demonstrated. However, there may be instances where stack emissions contain toxic materials that must be evaluated with the same procedure used in in-plant industrial hygiene.

Ranging from the reduction of ultraviolet light from the sun due to hazy atmospheres to inflammation of the eyes, mucous membranes, and respiratory system, the effects of air pollution on man will vary according to the specific reaction of the individual and the degree of pollution. To date, results of surveys in polluted areas have been inconclusive insofar as health effects are concerned. This is borne out by the refusal of most courts to consider health injury in litigation involving air pollution. In these cases, the tendency has been to evaluate the pollution on the basis of nuisance and damage to property.

Effect on Animals

Foundry emissions contain no known contaminants in concentrations which affect the well-being of domestic animals.

Effect on Vegetation

While the growing of certain plants in the immediate vicinity of a foundry has been shown to be unwise, instances of crop damage traceable to foundry operation have not been substantiated. As a district becomes industrialized, the surrounding agricultural land becomes less and less desirable for its original purpose. In some cases, the value of the land becomes so great due to nearby industrialization that it becomes uneconomical to continue to raise crops on it. Other problems which affect the growing of crops in areas surrounding industrial districts include stream pollution and the "poisoning" of soil by seepage from settling basins, and the like.

Effect on Property

The estimated annual cost of corrosion in large industrial areas is tremendous; however, such corrosion comes from sulfur dioxide and other acid-gases in the atmosphere emitted by industrial plants and also from all types of buildings such as homes, shops, churches, hotels, schools, and the like, employing heating equipment which burns sulfur-bearing fuel; industry alone cannot be held responsible for corrosion due to air pollution. It is true, however, that there is apt to be more corrosion in areas in the immediate vicinity of plants which use large amounts of fuel in which gases containing sulfur compounds are discharged to atmosphere.

With respect to particulate contaminants, it is necessary to differentiate between the emission of coarse solid particles which may create a nuisance in the immediate vicinity of the plant and the emission of extremely fine particles or fumes which are ordinarily carried for miles by prevailing winds without settling. The former instance may be termed "local nuisance" and often results in complaints from those whose laundry on the clothes line has been soiled by settling material, or from owners of cars parked in nearby lots, etc. Local nuisances resulting from the settling of coarse material discharged to atmosphere are the source of most neighborhood air pollution complaints and are the ones most easily corrected.

The effect of the fine material which is distributed over large areas is debatable and may be aesthetic rather than economic in significance. Fortunately, pollution problems of the magnitude encountered in Los Angeles are rare. Where widely dispersed solid and liquid particles create problems, unfavorable topography and meteorological conditions play important parts in creating these problems. Oddly enough, the very fine material, because of its visibility in the air, may create more complaints from a given area than does the coarse material which quickly settles. Since, in coping with an air pollution problem the psychology of the public reaction to the problem is important, it may be desirable to completely eliminate visible discharged material whenever practical from an initial and maintenance cost standpoint.

Factors Exaggerating the Problem

If the foundry industry's air pollution problem were confined to the collection of solid contaminants from shakeout and cleaning room operations, the physical difficulties involved in satisfactory collection would be minor and the financial hardship would be minimized.

It should be pointed out also that besides gray iron founding there are other major branches of the foundry industry, such as nonferrous, malleable, and steel. Each of these has air pollution problems peculiar to it, although they all have some in common.

The physical difficulties of satisfactory collection of some types of foundry pollutants are not easily solved and in some cases the cost of satisfactory collection may be prohibitive. For example, in many nonferrous shops, a large number of small furnaces is used. Because of the different alloys being melted, the operation of the furnaces may be intermittent, some not being used more than once a week. If all are connected to a single collector, needless horsepower is used during furnace stand-by time. If each furnace is connected to its own collector equipment, space and cost may be prohibitive.

Emission rates of various foundry sources vary even with the same piece of equipment. Thus, one must design collection equipment satisfactory for the highest anticipated emission rate.

Furthermore, many foundry effluents are hot and must be cooled before collection. If recirculated water is used for cooling, corrosion problems may be introduced; if fresh water is used, water cost may be high. Most metallic oxides from melting operations are less than 0.5 micron in size, requiring very efficient equipment for satisfactory collection.

After collection there is often a serious problem of disposing of the collected materials.

Sources of Foundry Pollutants

For convenience, pollutants discharged by foundries may be classified as follows:

1. Effluents from dust-producing operations within the plant.
2. Odors and gaseous compounds.
3. Effluents from furnace operations.

The problems arising from each type of contaminant listed above and the methods of control of pollution from these types of contaminants vary with the nature of the specific problem.

Effluents from Dust-Producing Operations

The widespread adoption of local exhaust equipment by modern foundries for removal of dusts and gases inside plants to improve working conditions has created a potential pollution problem which may vary from the "nuisance" stage to a general air pollution problem extending over a moderate area. It is fortunate, however, that in most foundries exhaust air is passed through dust collectors which remove the major portion of the solid contaminants before the air is discharged to atmosphere. In fact, there are few industries which have more universally adopted dust collectors of one type or another than has the foundry industry. Instances where dust-bearing ventilation air is discharged to atmosphere without cleaning are very rare. Having selected a proper dust arrester no particular problems arise in connection with the prevention of air pollution from sources of this nature.

Dust Particle Size

The composition and particle size of dusts from various foundry operations will vary considerably. For example, dust from a casting shakeout is high in very fine carbonaceous material and is normally entrained in air containing appreciable water vapor. On the other hand, dust from the grinding of castings includes coarse freshly fractured particles, along with elemental iron, iron oxide, clay particles, etc. The coarser dust from the grinding operations is more easily separated from the exhaust air stream than are the extremely fine particles.

The selection of equipment to collect the given dust will depend in great part on the particle size, shape, density, and concentration range of the material to be collected and on the collection efficiency desired or required by local ordinance, atmospheric conditions, or plant location.

Odors and Gaseous Compounds

Odors

Up to this time, primary emphasis in correction of air pollution from foundries has been placed on the discharge of inorganics—metal dust, sand, and fly ash—where visual inspection has shown the need for corrective action. However, even where every step has been taken in suppression of such discharges to the atmosphere, neighborhood complaints may continue as a result of disagreeable odors, or condensation of oily films, with the consequent discoloration of painted surfaces.

While the precise mechanism of the sense of smell is not fully understood, it is known that the olfactory nerves respond in a varying degree to different gases. Some odors such as hydrogen sulfide are offensive to practically all people, but others may be considered pleasant or disagreeable depending upon the opinion of the individual. Odor bears no relationship to toxicity, and some poisonous gases have a rather pleasant odor. People are sensitive to odors in varying degrees, and the sense of smell is readily and quickly acclimated to its environment. For instance, with constant exposure to a specific odorant, an observer may notice the odor for only the first few minutes, but thereafter it is no longer detected. Removal of the odorant normally results in prompt and full recovery of the sensitivity of the olfactory mechanism.

Because of the recuperative powers of the sense of smell, an observer at some distance from a plant may, with shifting winds, be more frequently aware of the odors released than operators directly within the plant area. Likewise, cyclical releases from batch operations are more frequently noticed than continuous exhaust. Therefore variations in response between individuals and in exposure time make the sense of smell a poor quantitative guide to odor concentration or toxicity.

Gaseous Compounds

Core oils, quenching oils, resins, and other organic materials required in foundry operations generally have unobjectionable odors as received and while retained at room temperatures. However, when used and subjected to heat, the formation of aldehydes, unsaturated hydrocarbons, and other odorous compounds result from distillation and pyrolysis. Few products of complete combustion have detectable odors, and the principal exception in foundry operations is sulfur. All compounds whose molecular structure consists of hydrogen, carbon, and oxygen, are odorless upon complete oxidation since the end products are water vapor and carbon dioxide. Consequently, in order to determine the source for odor complaints, primary emphasis must be placed on those foundry operations which liberate combustible type vapors, gases, or mists.

The most common foundry source of vapors is exhaust from core-baking ovens. Others include exhaust gases from oil-vaporizing furnaces for metal chips prior to metal-melting operations, paint-baking ovens, shell molding, oil-quench tanks, draw furnaces, and core-oil vapors during metal pouring operations.

Most vapors when discharged to the atmosphere may not settle but may concentrate in a particular location but because the weight of a sub-micron particle is millions of times that of a gas molecule it is more likely to settle. On the other hand when the stack gases contain visible liquid aerosols, these small particles are quickly absorbed, vaporized, or sublimed in the surrounding atmosphere, to be sustained and carried downwind. Dispersion occurs only through dilution by turbulence, or diffusion. Consequently under unusual weather conditions, identifiable odors can occasionally be detected miles from their source of liberation. Weather conditions being constant, the rate of release frequently determines the distance from its source that a specific odorant can be detected

Physical Difficulties Involved in Satisfactory Odor Elimination

In general, the discharge of combustible vapors through high stacks has not proved successful in the elimination of odor complaints. Where they have been employed in other industries, there has been a reduction of intensity of odor, but an increase in number of complaints. High stacks introduce a secondary problem of fire hazard resulting from the collection of condensate inside the stack, which frequently prevents their employment for combustible type fumes. Dry-type-particulate-collection methods such as fabric filters offer insurmountable cleaning problems and fire hazards when combustible or condensible vapors are present. Water scrubbing systems have had limited usage in the field of combustible vapors. The addition of water to hot combustible vapors often may result in the formation of organic acids, requiring the use of neutralizers or corrosion-resistant construction for the scrubber. It is recognized that the scrubber will remove a large portion of the condensible fractions of the combustible vapors. Usually, however, the more odorous materials are noncondensible in water. Any collected material must be buried or burned, as it usually is unsuitable for normal sewage disposal.

Destruction of the combustible vapors can be accomplished by completing the oxidation, namely, through direct combustion by heating the vapors to temperatures of 1200 to 1500°F or by catalytic combustion at temperatures of 1000°F or lower. Where concentration of the combustible matter is high, recovery of the heat generated may offer opportunities for partial or full recovery of the cost of the corrective equipment. Combustion methods have their greatest adaptability to the exhaust from ovens, furnaces, and other types of equipment where the vapors are generated within confined spaces. This permits treatment at minimum initial and operating cost. The cost of correction varies somewhat inversely as the vapor concentration of contaminant.

The control of core-oil odors liberated during a metal pouring operation is a problem. In most cases, a large amount of air is exhausted, even if a cooling conveyor follows the pouring operation. The concentration of combustible matter is so low that it throws direct combustion out of the picture. These odors can, of course, still be consumed by the catalytic combustion process, but this would greatly increase the cost, perhaps beyond present economic bounds. This all points to the fact that wherever combustible gases, vapors, or odors are released, it is imperative that they be collected in the lowest practical volume of air when subsequent treatment is required.

Effluents from Ferrous Furnace Operations

The principal types of ferrous furnaces used in the foundry industry are:

a Cupolas.
b Electric melting furnaces.
c Air furnaces.
d Open hearth furnaces.

Cupolas

Over the past few years the problem of air pollution from cupolas has been given more attention than the problem of emissions from any other foundry operation. The reason for this is the complexity of the problem, the difficulty of determining the nature and amount of emissions, and the moderate to high cost of equipment suitable to remove the mixture of cinders, dust, and extremely fine fume from the effluent cupola gases.

It is doubtful that sampling procedures employed to date in studying cupola emissions give an accurate or reproducible picture of such variables as gas flow, weight of solids discharged, and particle size of the discharged solids. However, information has been published regarding tests conducted at certain foundries in the Los Angeles area and elsewhere. Up to 24% by weight of the solids emitted by three cupolas in Los Angeles County was below 10 microns in particle diameter. In order to comply with the provisions of the Los Angeles County air pollution code, it would be necessary to install gas-cleaning equipment capable of removing a large portion of this extremely fine material.

On the other end of the scale was a maximum of 74% of the total weight of the solid effluents which was coarser than 325 mesh. This is the material which normally settles on the foundry roof and adjoining property creating a nuisance and a costly cleanup job.

The problem of selecting gas-cleaning equipment for iron foundry cupolas depends on the degree of cleaning efficiency required by neighborhood occupancy, existing pollution codes, and topographical and meteorological conditions in the surrounding area. For example, if it is merely desired to prevent the deposition of cinders and coarse dust on the foundry roof, a cupola stack washer may be installed which will trap the offending material but permit the intermediate and fine solids to pass through to the atmosphere.

Where a local nuisance or air pollution problem exists, it is essential to trap not only the coarse material but all of the remaining particles which could be expected to settle over the area in question. The removal of solid particles in the range of plus two microns can be effectively accomplished in high-efficiency scrubbers or centrifugal collectors. Even these devices, however, will permit the extremely fine fume to escape in a visible plume which may, under certain circumstances, contribute to the general air pollution of relatively large areas.

It has been stated that only electrostatic precipitators and cloth filters are capable of removing the extremely fine particles from cupola gases, at least to the degree required by a very stringent code, or to the extent that all visible solids in the effluent gases are removed. High efficiency cupola-fume-control installations have included baghouses. Many of these require manual shaking while some installations have mechanical shaking devices. There are several installations employing completely automatic, tubular, cloth-filter-type dust collectors using synthetic filter bags in conjunction with cooling of the hot gases prior to filtration.

Several installations employing electrostatic precipitators have been made. To successfully apply electrostatic precipitation to foundry-cupola-fume collection, it is necessary to determine the temperature at which the peak resistivity of the fume occurs and to design the gas-conditioning system to maintain a gas temperature well above or below that in which the resistivity reaches its highest point.

In all cases, whether baghouses or electrostatic precipitators are employed as the gas cleaning means, it is necessary to maintain efficient secondary combustion in the cupola stacks. Where secondary combustion is not practiced, the operation of the gas-cleaning equipment is adversely affected. Maintaining a reducing atmosphere in the cupola stack will carry over to the gas-cleaning equipment unburned oil vapor and tarry matter as well as coke fines and other combustibles.

In the last analysis, it is the responsibility of foundry management to determine its requirements with respect to low, medium, or high efficiency cupola-gas-cleaning equipment. In many areas, it is doubtful that stringent air pollution codes will be required, in others, it is inevitable that from year to year, more rigid restrictions on industrial plant effluents will be put into effect. In the latter areas, a decision must be made based on the economics of installation of control equipment designed to meet only present requirements, or equipment which not only meets present requirements but which will satisfy any reasonable future restriction on cupola emissions.

Electric Melting Furnaces

The air pollution problem from the operation of electric melting furnaces differs greatly from that of cupolas,

and there are certain complicating factors peculiar to this type of melting operation. Differing from the emissions from gray iron cupolas, the particle-size range and other characteristics of electric furnace fume are quite uniform. A typical fume from an electric-steel-melting furnace would be expected to have a particle size in the range of 0.01 to 2.0 microns. Because of this fineness, there is less choice on the part of the individual foundry operator with respect to the type of equipment and the degree of gas cleaning required in his area, i.e., only the most efficient air cleaning equipment can be considered.

In terms of grains of solids per cubic foot of exhaust air, the quantity of emissions discharged to atmosphere from an electric melting furnace is not considered great because of the relatively high air volumes required to produce effective ventilation at the furnace. In terms of the solids emission rate expressed in pounds per hour or pounds per ton of metal poured, the picture is somewhat different. Throughout the furnace cycle the average of solids emissions would range from eight to 20 pounds per ton of metal poured. In terms of the mass rate of emission specified by most air pollution codes, wet scrubbers or other devices capable of removing 75% by weight of the fume would satisfy code requirements. During certain phases of the melt cycle, the quantity of emissions increases greatly, particularly during oxygen lancing, and collection efficiencies in excess of 90% by weight would be required to meet air pollution-code weight restrictions. Unfortunately, the extremely fine particle size and great surface area of electric furnace fume results in the discharge to atmosphere of a conspicuous and characteristic plume which will not meet the opacity restrictions in some air pollution codes, even when weight requirements are met.

To remove the solid contaminants from electric furnace emissions to the point where a visible discharge is eliminated requires collection equipment of the highest order of efficiency, such as cloth filters or electrostatic precipitators. It is estimated that the concentration of fine solids in the effluent air from an electric furnace-fume-control system must be less than 0.05 grain per cubic foot of air if a discharge free from opacity is desired.

Several electrostatic-precipitator installations have been made in connection with the control of air pollution from larger electric furnaces. As in the case with cupolas, it is necessary to determine the resistivity of the furnace fume and to plan on cooling the gases to the point of minimum resistivity.

There are about 50 installations in operation employing cloth-filter collectors for the cleaning of electric furnace emissions. The cloth-filter dust collectors are highly efficient under all operating conditions and generally result in an effluent free from visible solids upon discharge to atmosphere. The principal problem in applying these to electric furnace-fume control is the estimation of the proper exhaust volume to accomplish the following:

1 Provide adequate fume control at the furnace.
2 Provide sufficient cooling at the furnace to protect the exhaust hood into which the hot furnace gases and fume are drawn.
3 Cool the furnace-ventilation air and gases below the maximum operating temperature of the filter medium employed.

The volume and temperature of gases entering an electric-furnace-fume control system depend on the *level of activity* within the furnace, rather than on the physical dimensions of the furnace itself. This level of activity is a function of the actual power input to the furnace and of the exothermic metallurgical reactions which occur during various phases of the melt. Thus, a furnace with a high melt-down rate and prolonged oxygen lancing would require more ventilation and cooling air than would the same size furnace being operated at a lower capacity and without oxygen lancing. Carrying this concept further, the duplexing furnace would require less ventilation air and create lower ventilation-air temperatures than would a similar furnace melting steel. Where a single furnace is exhausted, an intermittent type baghouse may be employed for reasonably short melting cycles, and provisions made to shake the collected fume from the filter bags whenever the furnace roof is swung out for charging or back charging. Where two or more furnaces are ventilated by the same fume-control system, continuous automatic baghouses are required in which one compartment shuts down at a time for bag cleaning, while the other of the compartments continue in operation. Also, the exhaust capacity per furnace can be reduced because of the tempering effect of cooler gases from one furnace on the hotter gases from another. Where duplexing furnaces are ventilated, continuous automatic cleaning equipment is required because of the custom of hot charging and perhaps continuous pouring which serve to eliminate furnace down time.

Of the three principal methods for electric-furnace ventilation (overhead canopy hoods, roof mounted hoods, and direct shell tap), exhaust hoods encompassing the top of the furnace and supported on the furnace roof are most commonly employed. Comparing the roof mounted hood to the direct shell tap method of ventilating a furnace, it has been shown that the total quantity of air required is approximately the same so long as air cooling is employed in both methods. In cases where an overhead canopy hood is employed, a capacity roughly two to three times that required for either the roof mounted hood or direct shell tap is employed.

Air Furnaces

To date, air furnaces in foundries have been minor sources of air pollution with respect to the over-all problem facing the foundry industry. Where pulverized coal is the fuel employed, the air-borne solids discharged to atmosphere comprise mainly fly ash with only a minor proportion of metallic oxide.

Open-Hearth Furnaces

In some steel foundries the open-hearth furnace is used. From the atmospheric pollution viewpoint, open-hearth furnaces are characterized by wide fluctuations in dust loading, gas temperature, and gas volume during the melting cycle. In some cases baghouses and electrostatic precipitators have been used to alleviate the pollution problem.

In the foundry industry, open-hearth furnaces are gradually being replaced by electric furnaces.

Effluents from Nonferrous Furnace Operations

Nonferrous foundry operations play a minor part in the over-all foundry pollution problem. However, emissions from any given plant, because of local conditions, may create a neighborhood problem. Because of the wide variety in melting equipment for nonferrous alloys, no attempt will be made either to classify furnace types or to treat the specific air pollution problem involved.

Brass, Bronze, and Copper Alloys

Various metallic elements contained in copper-base alloys have higher vapor pressures than copper so that the composition of emanations from the molten alloy normally will vary according to the minor metals present in the melt. For example, fume from a brass furnace is composed principally of zinc oxide with a minor content to lead oxide, etc. Equipment designed to remove metallic oxides from these furnace gases is designed from the viewpoint of zinc-oxide removal because of the predominance and peculiar characteristics of zinc oxide.

The plume from furnaces and cupolas melting brass or bronze alloys is white and usually does not arouse neighbor-

hood complaints; nevertheless many air pollution ordinances would require collection for one reason or another. The fume is fine—of the order of less than 0.5 micron—so that only high efficiency equipment can do a satisfactory collection job. Unlike electric furnace emissions, stack temperature from furnaces and cupolas conventionally used in nonferrous work are too hot even for the new type fabrics, thus precooling is also necessary.

From alloys of copper with beryllium, a serious air pollution potential exists because of the high toxicity of beryllium oxide. Despite the large amounts of lead processed in industry and with its known capacity to produce lead poisoning readily, no cases of community illness have been traced to air pollution from such a source.

On the other hand, neighborhood cases of berylliosis have been verified when the atmospheric concentration was of the order of one (1) microgram per cubic meter of air. The Atomic Energy Commission has recommended that the atmospheric concentration should not exceed 0.01 microgram per cubic meter of air. This value has a safety factor of about 10 but it is based on actual air pollution studies. Thus it is apparent that only the most efficient gas-cleaning equipment will be suitable whenever this toxic material is present in stack emissions. Disposal of collected beryllium dust or fume is also a serious problem.

Phosphorizing of copper presents an especially difficult problem. When molten copper is inoculated with white phosphorous, dense clouds of phosphoric acid anhydride (P_2O_5) are given off. Because the anhydride is very hygroscopic and is often used for drying gases, it would seem that a wet-type collector would do a satisfactory job of fume control. However, experience has shown that wet scrubbing and electrostatic precipitation are necessary for foundry applications if corrosion of neighboring structures is to be avoided.

Because of the formation of concentrated phosphoric acid, wet scrubbing before final collection is also necessary in order to prevent excessive corrosion of the electrostatic precipitator. Frequently stainless steel or other corrosion-resistant material is necessary in ductwork and acid-exposed parts of the system.

The recovered phosphoric acid is not of sufficient purity to be marketable and the selling price of phosphoric acid presently does not justify the cost of purification.

In some areas, the phosphoric acid may not be discharged into streams because of the danger of changing the natural pH of the water.

The disposal problem is probably best solved by converting the acid to calcium phosphate, a fertilizer which may be sold or given away for the cost of hauling.

Alloys of Aluminum and Magnesium

As in the case of red metal alloys, aluminum and magnesium and their various alloys are melted in a wide variety of furnaces and melting pots. Classification of melting equipment or generalization on fume-control problems associated with each type of melting equipment is difficult.

Normally the fluxing agents used in melting white metal create the air pollution problem and the fume generated is composed of either chlorides, fluorides, sulfur dioxide, oxides of the alkali metals or the oxides of the material in elements comprising the melt. A whole new set of problems may be introduced by the use of fluorine compounds as fluxes, in that both solid and gaseous fluorides are emitted. In normal practice these emissions are not large enough to cause a problem.

The removal of solid fluorides presents no more problems than do the other solid contaminants in the effluent, however, special means of eliminating gaseous fluorides are required. Certain types of scrubbers have been effective in removing gaseous fluorides, but special construction to minimize corrosion and in some cases, means of chemically treating the effluent water from the scrubber are indicated. It has been found that where dry-type collectors are employed, certain finely divided reagents may be introduced into the gas stream to adsorb the gaseous fluorides so that the latter are removed by the dry type collector along with the solids.

In other cases, where favorable meteorological and topographic conditions exist, tall stacks may be recommended as a means of dispersing noxious gaseous compounds.

Gas Cooling

Gas temperature is one of the principal problems confronting the foundry operator who must install air pollution control equipment to clean furnace gases.

Stack temperatures as high as 2000°F are encountered in cupolas where secondary combustion occurs and some degree of gas cooling is often required.

Cooling by radiation and convection is ordinarily accomplished with U-tube coolers (familiar sights in many nonferrous smelters) or heat exchangers such as waste heat boilers or forced draft tubular condensers. U-tube coolers require a relatively large amount of ground space and require considerable lengths of heavy steel ductwork from which heat is radiated at a low rate. U-tube coolers lack flexibility with respect to final temperature adjustment, and their use often results in inadequate cooling in hot weather and overcooling in the winter time.

Tubular heat exchangers, utilizing outside air supplied under forced draft around the outside of the hot-gas carrying tubes, have been successfully employed. Because of the use of forced draft for secondary cooling air, tubular-heat exchangers are relatively economical insofar as space requirements are concerned and offer more flexibility in final temperature adjustment than do either U-tube condensers or waste heat boilers. The use of any of the above cooling devices is more attractive if they are supplemented by either spray cooling or the use of tempering air for final temperature adjustment.

Cooling gases already high in water vapor content is frequently accomplished by the admission of outdoor air through full modulating bleed-in dampers. Precise regulation of filtration temperature is readily accomplished by this method, but since the outside air admitted for cooling purposes must also pass through the filter bags, it is obvious that the size of the filter itself must be considerably larger for tempering-air cooling than for the other two methods listed above. In some cases where the gas being filtered is an explosive concentration, the admission of oxygen is objectionable for reasons of safety.

Since a gas-cleaning system installed for air pollution abatement is usually a nonproductive expenditure, the equipment cost must be kept to a minimum. For this reason, spray cooling of hot gases is the most attractive of the available methods since it is reasonable in first cost, easily maintained, and results in only a nominal increase in the volume of gas to be filtered.

Economics

Air pollution control equipment in the ferrous foundry industry is a nonproductive expense. In other words, the material collected from dust and fume-producing operations is worthless and often requires additional expenditure for disposal. In the case of nonferrous foundries, the collected metallics may have some value, sometimes sufficient to pay for the handling of the material after collection. In no case, however, would the value of collected fume and dust in a nonferrous foundry be comparable to that released by primary and secondary nonferrous smelters.

There have been one or two instances in steel foundries where the collected iron oxide from electric furnace ventilation gases is bagged and charged into the furnace for carbon control. Here again, the savings are minor com-

pared to the capital and operating costs of the air pollution control equipment.

But from the installation of air pollution control equipment some worthwhile benefits may result. Such as:

1 Cleaner working conditions.
2 Better public and employee relations.
3 Better visibility in the plant areas.
4 Reduced maintenance of buildings and yards.

First cost is not always the criterion of the most economical pollution-control installation. The capital investment should be as low as is commensurate with existing and anticipated code requirements and with anticipated operating and maintenance costs. Preferably, the over-all installation, operation, and maintenance costs should be estimated for the expected life of the equipment and the selection made on the basis of the apparatus which meets present and anticipated code requirements and shows the lowest over-all cost.

REFERENCE

Foundry Air Pollution Control Manual. American Foundrymen's Society, Des Plaines, Illinois (1956).

Informative Report No. 2

Gray Iron Foundry Practice and Air Pollution

This report is intended to furnish a brief description of typical foundry operations. Practices in steel, malleable, and nonferrous foundries are similar, the principal differences being in the types of metals processed and the method of melting.

Most production shops are highly mechanized or automated while the jobbing shops are not. Automation cannot easily be adpated to the latter because castings made by them vary in weight from a few pounds to several tons.

In production shops one can find castings being poured, shaken out, and cleaned by automatic devices. Whereas in jobbing shops, every operation may be done manually depending on the weight of type of casting.

Regardless of the type of foundry, in-plant air pollution problems are an unavoidable result of the casting process. One cannot melt or pour metal without creating fume and hot, dry sand cannot be shaken from flasks without creating dust.

In endeavoring to comply with local and state plant safety and hygiene requirements, most foundries have improved the dust and smoke problem in the plant, but added to the air pollution potential of the neighborhood by emitting the material to the atmosphere.

Most foundries are cognizant of the air pollution nuisance; however, much of the equipment necessary to eliminate it is so expensive that it creates a problem of economic feasibility. The added burden of cost may cause a small foundry great hardship while a larger foundry which can distribute the cost over more volume produced may not be placed in such an adverse condition. (See Report #1 of Committee TI-7.)

In order to understand more clearly the air pollution problem faced by the foundries, definitions of terminology used in this report may be helpful to those who are unfamiliar with the field of air pollution control.

Definitions

Air Pollution has been defined as the presence in the air of any substance that is foreign to normal air. Industry's problem concerns the presence of man-made contaminants that can interfere with the health, safety, and comfort of its neighbors and the enjoyment of their property.

Dusts are formed from solid materials by physical force such as crushing, grinding, high temperature, etc. Particle size ranges from microscopic to sub-microscopic. However, particles above 50 microns in size settle rapidly. For purposes of this manual, such materials as fly ash are included in the definition of dust.

Fume is a term applied to fine solid particles dispersed in air or gases and formed by condensation, sublimation, or chemical reaction. In reports of Committee T1-7, the term is used to mean oxides of metals.

Vapor is the gaseous phase of matter normally in the liquid or solid state.

Smoke is a type of emission resulting from incomplete combustion and consisting predominantly of small gas-borne particles of combustible material present in sufficient quantity to be observable independently of the presence of other solids in the gas stream.

Mist is a visible emission usually formed by a condensation process or a vapor-phase reaction, the liquid particles being sufficiently large to fall of their own weight.

Gas is a formless state of matter completely occupying any space.

Dust Particles Size Defined. The sizes of air-suspended materials which cause air pollution are measured in microns. A micron is a small unit of length, 25,400 micron lengths being equal to one inch. In sharp contrast with the small size of the micron are the sub-micron sizes of particles from metal melting, the majority of which may vary from one-half down to one-hundredth of a micron in size.

Not only are the smaller sized particles given off in greatest numbers during metal melting, but they have the greatest tendency to remain air-borne, and are exceedingly difficult to collect and to clean from an exhaust stream. Strangely enough, a single particle less than one-half micron in size cannot be seen with an optical microscope, although their multiple presence in furnace-stack gases is easily visible to the naked eye due to the diffraction in effect increases their visibility.

Common Foundry Terms

For those not familiar with foundry operations, some common terms are defined as follows:

Air-Rammed. Term applied to tamping operation, using compressed air tamping tool.

Pars. Ribs of metal or wood placed across the cope portion of a flask. Sometimes called "cleats." In some cases used as the drag to eliminate use of bottom boards.

Bottom Board. A flat surface secured to bottom of flask to retain sand in mold.

Bottom Poured. Term signifying the pouring of metal from bottom of ladle as opposed to lip, shank, or teapot pouring.

Chaplets. Metal supports or spacers used in molds to maintain cores, or parts of the mold which are not self-supporting in their proper positions during the casting process.

Chills. Steel shapes inserted in mold to aid in metal solidification.

Cope. The upper or topmost section of flask or mold.

Core. A separable part of the mold (usually made of baked sand) which creates openings and various shaped cavities in the casting.

Core Box. Form in which sand is packed to produce a desired cavity required in the casting.

Core Plates. Heat resistant plates used to support cores while being baked; may be metal or nonmetallic, the latter being a requisite with dielectric core baking.

Drag. The lower section of flask or mold.

Facing Sand. Specially prepared molding sand mixture used in the mold adjacent to the pattern to produce a smooth casting surface.

Flask. A box without top or fixed bottom used to retain sand in which

mold is formed.

Gaggers. Shaped steel supports which reinforce sand in mold.

Gates. A general term which indicates the entire assembly of connected columns and channels conveying the metal from the top of the mold to that part of it forming the casting cavity proper.

Heads. Term applied to reservoirs of metal which feed casting. Term also applied to patterns which form sand cavities for reservoirs.

Matched on Boards. Term descriptive of act of attaching split pattern back to back on platforms to form an integral piece.

Mold. The material containing cavity into which molten steel is poured.

Muller. A mechanical device which mixes sand.

Parting Compound. A fine powder which deters adhesion between cope and drag molds.

Pattern. Model of wood or other material used in making mold.

Reclaim Sand. Sand which has been used previously.

Reversal. Method of feeding mold by changing position of flask after pouring.

Riser. See "Heads."

Runner Cups. A refractory funnel which channels molten steel into mold.

Sand Slinger. A mechanical device which throws sand by centrifugal action into flasks and core boxes.

Slag. A fused, nonmetallic substance which insulates the molten steel and extracts certain impurities.

Sprue. The vertical channel connecting the pouring basin with the skimming gate, if any, and the runner to the mold cavity, all of which together may be called the gate. In top-poured castings the sprue may also act as riser. Sometimes used as a generic term to cover all gates, risers, etc., returned to the melting unit for remelting. Also applies to similar portions of master patterns, pattern die, patterns, investment mold and the finished casting.

Stopper. A device inserted in ladle which controls the flow of metal.

Tapping. Term applied to the release of molten metal from furnace into ladle.

Vents. An opening in mold or core which allows for the escape of steam or gases.

Occurrence of Air Pollution Problems

The occurrence of air pollution problems in the foundry may start with the unloading of incoming raw materials and cease with the shipment of the end product. Following are listed some of the sources of air pollution in the operation of a foundry with a description of the emission.

Unloading

Material	Emission Classification	Description
Coke	Dust	Heavy particle
Iron	Dust-iron oxide	Heavy particle
Limestone	Dust-calcium carbonate	Heavy particle
Sand	Dust-silicon dioxide	Heavy particle
Binders	Dust Vapors-organic (oil)	Light & heavy particles

Cupola

The first American cupola was erected in 1820 and has become the major melting furnace for the production of iron castings. It is a simple vertical cylinder made of boiler plate; lined with fire brick to withstand temperatures above 3000°F and equipped with air inlets (tuyeres) near the base to allow combustion air to pass up the inside of the cylinder. At the front of the cupola near the base is a hole (tap hole) from which the metal and slag flows. Near the top, approximately 20 ft above the base, is a door (charging door) through which the fuel (coke), flux (limestone), and metal are introduced (charged).

In operation, the base of the cupola is closed with hinged doors. A layer of sand is rammed over the doors to protect them from the heat and flow of molten iron. A coke bed is placed on the sand bottom filling the cupola to a height of 4 to 6 ft. After the bed of coke has been properly burned, alternate layers of coke, flux, and metal are charged into the cupola until it is filled to the charging door. The combustion air is then forced in through the tuyeres causing the coke to burn and melt the iron. As a layer of coke burns and a layer of metal has melted, the alternate layers of coke, flux, and metal descend allowing room for more material to be put in at the charging door. The molten iron flows out through the tap hole in a continuous or intermittent stream.

Cupola Hot-Blast Systems

Many foundries preheat the cupola-blast air in order to attain a faster melting rate at a higher and more uniform temperature with improved fuel economy.

Two types of hot-blast system are available: one is the externally fired preheater that operates similar to a residential heating unit and has no effect on cupola emissions. The other is the recuperative type which uses the potential heat of the effluent cupola gases as a fuel. This system when used in conjunction with a closed top cupola and an appropriate dust collector, reduces the effluents to the atmosphere from the cupola operation.

In the recuperative-type hot-blast system the stack gases are pulled into a combustion chamber where they are burned raising the temperature of this zone to about 1700°F. The gases are then pulled through a distributing chamber which consists of a series of heat exchanger tubes, similar to boiler flues, then through a secondary distributing chamber. The blast air is forced around the heat-exchanger tubes in an opposite direction to the flow of hot combustion gases within the tubes, thus preheating the blast air. The heat exchanger acts as a primary separator.

Emissions from Cupola Melting

Charge Material	Emission Classification	Description
Coke	Dust, fly ash	Light particle
	Smoke, carbon dioxide	
	Carbon monoxide	—
Flux	Dust	Light particle
Metal	Dust, metal oxides	Light, heavy particle
	Metal oxides	Light particle

From the cupola the molten metal is transported to the pouring area where it is poured into the mold cavities to form the castings.

Nodular Iron

One of the greatest advances in the iron foundry industry during the past decade has been the advent of nodular iron also referred to as spheroidal graphitic (S.G.) and ductile iron. This new material was first announced in 1947 by both the British Cast Iron Research Association and the International Nickel Company with each holding a patent covering a method for producing an iron with the graphitic carbon in the spheroidal form rather than in the flake form. Graphitic carbon in the spheroidal form creates a minimum number of discontinuities in the metal matrix, resulting in a stronger, tougher iron.

The British Cast Iron Research Association patent covers the use of Cerium as the nodularizing alloy while the International Nickel Company patent covers the use of magnesium. The magnesium-alloy treatment has found the greatest favor both in the United States and abroad, thus it is the only method covered here.

The production of nodular iron consists of melting a suitable base iron (low silicon, manganese, phosphorous, sulfur, and relative high carbon) and rapidly plunging or pouring it into a ladle containing the nodularizing alloy

(usually two to three per cent of a magnesium-ferro-silicon alloy containing approximately 10% magnesium and 45% silicon with the balance iron). The result is a flash as the magnesium burns and the creation of fumes as magnesium oxide forms plus the retention of sufficient magnesium in the iron to cause the graphite to remain in the spheroidal form.

The production of nodular iron is generally carried out in an area that has adequate ventilation facilities with atmospheric exhaust blowers to remove the magnesium oxide fumes from the area. The fumes are the only effluents and are not in great enough quantities to create a serious problem.

Molding

The most widely used process is green-sand molding which is the only process covered here. The molding process starts with the preparation of the sand for the molds. Molding sand is usually prepared in a mechanical mixer by adding a binder (bentonite) and a gas forming material (sea coal) to the sand during the mixing process. The binder coats the sand grains causing them to stick together when compressed under pressure. The sea coal is added to form a gas during pouring of the molds. The gas fills the voids between the sand grains thus producing a smooth finish on the casting.

The sand rammed around the pattern is squeezed to further compact the sand. The pattern is next withdrawn from the mold leaving the cavity. Cores may be placed in the cavity to form passages in the finished casting. After placing the proper cores in a mold the mold is closed and ready for pouring.

The iron is poured through a hole (sprue) in the top half (cope) of the mold. The mold is not disturbed until the metal has solidified then it is shaken out (removal of casting from the sand).

The air pollution problems encountered during the sand mixing, molding, and pouring operations are largely factors of in-plant environment control. The emission may be dust from sand mixing and dust, smoke, and fumes from pouring and shakeout. These emissions can usually be handled by simple exhausters and dust collectors and are seldom a source of nuisance complaints.

Molding Unit

The term "molding unit" refers to several sets of molding machines grouped together in such a manner as to feed molds to a continuously moving conveyor line, or pouring floor.

The molds move from the molding stations to the pouring area and then to the shakeout area in a continuous flow.

A molding unit usually requires a large initial capital expenditure. However, increased productivity usually makes it a worth-while investment.

The sources of possible air pollution problems from the operation of a molding unit are: sand mixing, pouring, cooling, and shakeout.

Molding units lend themselves to control of both in and out-of-plant air pollution problems by having the individual operations concentrated in a small area which is easily exhausted through suitable collectors. (See Report #5 of Committee TI-7.)

Shell Molding

The shell molding process was originally developed in Germany during World War II and has found limited application in the United States.

Shell molding is a technique for making castings in a mold having a wall thickness of only $^1/_8$ in. to $^3/_8$ in. thus the name shell mold.

The shell molding process consists of dumping (investing) a mixture of fine silica sand and a thermo-setting plastic binder (phenol resin) on a metal pattern that is heated to approximately 400°F. The heat of the pattern causes the binder to set, thus locking the sand grains in place. The excess sand and resin is dumped from the pattern and the adhering material still intact on the pattern is placed in an oven at 600°F for approximately one minute to fully harden (cure) the sand-binder mix. Upon coming from the oven the shell mold is rigid enough to be stripped from the pattern plate by means of lifting pins. The mold is then ready to be assembled and poured.

The principal advantages claimed for shell molding are:

1. Excellent surface finish.
2. Consistently close dimensional tolerances.
3. The process lends itself to mechanization.

The sources of air pollution problems from the shell molding operations are: sand and binder mixing, mold making, pouring, and shakeout. The effluents from these are dust, fumes, odors, and smoke. Mechanization of the shell molding process facilitates handling of the effluents with the proper control equipment.

Core Making

Cavities or passages desired in a casting are formed by using suitable cores in the mold assembly. For example the water passages in the block for cooling a gasoline engine may be formed by use of oil-bonded sand cores.

The making of cores causes neither an in-plant nor neighborhood air pollution problem. But during baking to harden the core, fumes from oil or other bonding material may create both an in-plant and an external air pollution problem.

Some foundries harden cores by the CO_2 process. In this process, core sand is mixed with sodium silicate (water glass); the core shaped according to pattern; and carbon dixoide injected. The core hardens at room temperature, acquiring sufficient strength to resist collapse under metal pressure.

This process, where it is applicable, eliminates the need for core baking.

Casting Cleaning

From the pouring stations the castings are transported to the cleaning room where they are cleaned, chipped, and ground.

The cleaning operation removes any sand that adheres to the castings. This is usually done by impinging metal shot or sand against the castings or by tumbling in a cylindrical-shaped mill with mill stars. In controlling the in-plant environment it is necessary to exhaust the cleaning equipment to remove dust and fine metallic particles through a suitable collector. (See Report #5 of Committee TI-7.)

After cleaning, the castings are chipped and/or ground to remove any nonessential projections such as fins or gates. The dust and metallic particles are usually exhausted by means of similar equipment as used above.

Conclusion

As previously stated, the greatest source of air pollution problems and nuisance complaints is the melting operation. Effective control of emissions from melting furnaces is complicated by a number of factors, such as:

1. The great number of *ultra-fine particles* in stack gases unfortunately makes such gases clearly visible in the form of a plume, even after they have passed through what is normally considered a high-efficiency dust collector. In contrast with metal-melting operations, other foundry operations do not produce large external volumes of ultra-fine dust particles.
2. *High Temperature* of furnace-stack gases usually requires the use of refractory-lined or heat-resistant alloy ducts, plus possible additions of water sprays for cooling the gases, before they can be handled satisfactorily by most conventional types of dust collectors. (See Report #5 of Committee TI-7.)
3. The large volume of furnace-stack gases, whether cooled with water sprays or dilution air, requires large-size dust collectors which would normally be expensive even without other complicating factors such as available space.
4. Use of water-spray equipment for stack-gas cooling frequently pre-

sents corrosion problems. These corrosion problems may be traceable to the nature of the available cooling water supply and to the gases absorbed by the spray water.

5 Air pollution control equipment for metal melting operations is an added operating-cost burden, usually without by-products that might reduce operating costs. (See Report #1 of Committee TI-7.)

Informative Report No. 3

Air Pollution Problems of the Investment Casting Process

Investment casting is a relatively new process derived from the ancient Lost Wax Art. Development of this art for industrial purposes was started during the second World War. It has since been advanced to become an important part of the cast-metal-forming industry.

The objective of this process is to produce small and medium size castings, in all types of metal, to close dimensional tolerances measured in a few thousandths of an inch. The major characteristic of this process is that for every casting made a pattern is required. Since the pattern is made of a disposable material, the mold surrounding the pattern is made in one piece without any parting such as would be required for a removable pattern. This is an important feature to insure close dimensional tolerances on the finished casting.

Each pattern is made by injecting a disposable material into a die to form a pattern. The dies are constructed of metal, in two or more sections, with accurate parting surfaces. In general practice, the disposable pattern material consists of wax. In some instances, for a high volume part of not too great complexity, plastic material is used. In one particular process, the material consists of mercury. In the mercury process, the pattern is formed at a sub-zero temperature and surrounded with a mold material at that temperature. The coated pattern is then allowed to warm to room temperature when the mercury will flow freely from the mold cavity. Pattern production, with any of these pattern materials, is not a source of external air pollution but may be involved with some in-plant problems. (See reference.)

Small patterns are set up in clusters, on a runner, to form a properly gated assembly to insure correct metal feeding. Large patterns are gated individually. For ferrous castings, the gated assembly is dipped in a slurry of fine silica powder and chemical binder to form a permeable and smooth coating on the surface of the pattern. The coated assembly is placed within a tubular metal flask. One end of the flask is sealed to a plate. The flask containing the pattern assembly is then filled with another slurry consisting of a blend of fine to medium-coarse sand and chemical binders.

For nonferrous casting, the pattern assembly is not dip coated. The pattern assembly is placed within a flask as described above and the flask filled with a slurry containing silica, plaster, and chemical binder.

The handling, blending, and slurry making of the fine sands presents an internal dust problem which can be controlled by a wet or fabric type dust arrester.

After the mold material, within the flask, has set and dried at room temperature for a prescribed period, the investment flask is dewaxed in a moderate-temperature oven where approximately 80% of the pattern material is removed. The molds are then placed in a high-temperature furnace and the temperature gradually elevated to 1600 to 1900°F for ferrous work and to 1200°F for nonferrous work. During this heat cycle, the residual wax is completely removed and the mold material converted to a ceramic to withstand the temperatures of molten metal.

At about the midpoint of the baking cycle, removal of the residual wax from the mold creates a considerable volume of fume combined with water vapor. Some fume and vapor may be created in the initial dewaxing process. This effluent from the plant may cause an air pollution problem due to unburned hydrocarbons combined with some odor. As far as is known, catalytic combustion or afterburning are the only practical methods of controlling these emissions in ferrous operation. For nonferrous work, the use of catalytic combustion may be ineffective due to contamination of the catalytic element by stray metallic fumes. Both methods are costly in initial installation and in fuel consumption needed to maintain the conversion temperatures.

After the molds have been baked to the required temperature they are ready for the pouring of metal. For the investment casting process, ferrous metals are usually melted by electrical induction. For small melts, up to 18 lb, induction-melting heat is obtained from static frequency changers ranging from 20,000 to 100,000 or more cps For the larger melts, rotating-frequency changers are used with frequencies of 960 to 9600 cps.

The normal investment casting mold requires a relatively small quantity of molten metal. Most investment castings, due to their complexity and thin sections, require superheated metal. Consequently, ferrous heats are usually limited to 100 lb in order to avoid alloy and temperature losses. In some investment casting foundries, ferrous melts are produced to direct-arc heat and the quantity melted is limited to that required by one mold, usually in the range of 10 to 12 lb.

For nonferrous melting, it is customary to use gas-fired crucible furnaces of the stationary or tilting type, melting from 200 to 300 lb. Induction heat, from static or rotating converters, is also used with melting capacities somewhat greater than for ferrous work. Because melting temperatures are lower there is less chance of alloy and temperature losses.

Since investment casting heats are usually small the smoke and fume discharged from the heat are small and do not contribute significantly to air pollution. However, with nonferrous metals containing an appreciable amount of zinc in the alloy, a considerable amount of fume is created which must be collected and removed to outdoors. In order to avoid air pollution the discharge of the collection system must be connected to a fabric-type dust collector. Zinc fumes also may be captured by supersonic or electrostatic precipitation but at an increased cost depending upon the size of the installation.

Following a cooling period, the cast cluster and mold material are removed from the flask by a press. Most of the mold material is removed from the cluster by vibration. Any residual mold material is removed from ferrous castings by salt-bath treatment. For nonferrous castings the residual mold material is removed by sandblasting. The cleaning operation involves a considerable amount of internal dust which can be captured by a wet- or fabric-type dust collector system. If salt-bath fumes become a problem a wet-type dust collector should be used.

Individual steel castings are removed from a cluster by abrasive discs or friction bandsaw cutting. Nonferrous castings are removed by standard bandsaw cutting or abrasive discs for the harder metals. Gates are then ground to specified requirements and any blemishes removed by filing and burring. The metal dust created in these operations can be captured by dry- or wet-type collectors.

In general, the investment casting process is a minor contributor to the

over-all air-pollution problem in an area. Most investment casting foundries work on a jobbing-shop principle and are usually limited to a small operation, employing about 150 persons. In the investment casting industry, as in other branches of the foundry industry, air-pollution control equipment is a nonproductive expense and the collected material is worthless.

REFERENCE

Engineering Manual for Control of In-Plant Environment in Foundries. American Foundrymen's Society, Des Plaines, Illinois (1956).

Informative Report No. 4

Instruments and Techniques for Measuring Foundry Air Pollution Emissions

With one exception, air pollution emissions from foundry operations can generally be assessed using the procedures and tools now in routine use by air pollution engineers. Equipment and procedures for this purpose are described by a number of authors including Magill, Holden, and Ackley,[1] the Manufacturing Chemists' Association,[2] Dalla Valle,[3] the Western Precipitation Corporation,[4] Kanter, Lunche, and Fudurich,[5] and the American Society of Mechanical Engineers.[6] Fairly well standardized procedures for the collection of both particulate and gaseous source samples from stacks and ducts are described along with procedures for area sampling, e.g., dustfall measurements, high-volume sampling of atmospheric air, etc.

The exception is the foundry cupola which presents unique sampling difficulties and about which little sampling information has been published. The inherent cyclic nature, the high stack temperatures, the small particle sizes, and the general stack inaccessibility associated with cupola operation combine to create a sampling problem which is not easy to solve. This report, therefore, is confined to a discussion of cupola emission measurements.

It must first be recognized that the objective sought here is not to outline the best sampling procedures which could be provided at our present stage of development for the extraction of the most accurate and most meaningful cupola emission data. Such an end could be reached only through an extensive study of this problem on a sound engineering basis. Rather, it is our purpose to contribute sufficient background information which will provide the air pollution control official, industry personnel, and others with a practical, workable technique furnishing, at worst, order-of-magnitude emission rate figures and allowing comparative emission rate measurements to be made.

In arriving at the procedures suggested, information was gathered in several ways. These included (*1*) inquiries to all full-time local and State air pollution control agencies in the United States, (*2*) private communications with representatives of several manufacturers of air pollution control equipment, (*3*) discussions with members of the Air Pollution Engineering Research staff of the U. S. Public Health Service, (*4*) reference to the literature as indicated in the Bibliography (see Appendix A), and (*5*) conduct of a sampling expedition to a large-scale foundry (see Appendix B).

Pollution created by cupola operation may be emitted in the form of gases or particulate matter. Gaseous emissions can be sampled by the use of freeze-out techniques, absorption or adsorption devices, or collection within evacuated chambers.[1, 2, 7] Once collected, the samples can be analyzed by various chemical, instrumental, or biological methods as are summarized in references.[1, 2, 8, 9, 10]

Since many gaseous contaminants are objectionable primarily from the standpoint of odor, evaluation of these emissions can be accomplished according to olfactory methods described by Nader,[11, 12] Byrd,[13] Mateson,[14] and Turk.[15]

The determination of particulate emission rates is of most interest at the present time and this requires the relating of a measurable quantity of such particulates to a known volume of the effluent stream as well as a knowledge of the average rate of volumetric discharge of the effluent stream. The quantity of particulate may be defined in terms of weight, number, "soiling power," or in other terms, but for the purposes generally of interest, the weight of the solids is normally utilized.

As the first step, the gaseous efflux rate must be obtained and this is usually accomplished by conducting pitot traverses over the stack area.[4, 6] It has been found that such traverses can be made at the charging door, at a sampling port near the top of the cupola stack, or at the top of the cupola itself. Of these locations, a sampling port located about two stack diameters below the top of the cupola should be preferable, at this location, velocity profiles should be relatively stable, temperature cycles are of lower amplitude than at the charging door, the cupola wall provides a much needed shield against radiant heat for the sampling team, stack velocities are higher and hence more easily measured, the danger of excessive carbon monoxide concentrations in the air breathed by the sampling team is minimized and the closest approach to classical stack sampling techniques can be made.

The obvious disadvantages are the need for a sampling platform at this level and the installation of the sampling port itself. Standard or blunt-end pitot tubes may be used quite satisfactorily and no difficulties should be encountered from plugging of either the impact or the static holes in these tubes. Because of the high stack temperatures, stainless steel probes will be necessary in most cases and heavy asbestos gloves must be provided for the operators. Stack velocities, especially when measured at the charging door, can be quite low (200–500 ft/min.) and these will create impact pressures (pitot tube readings) as small as 0.001 in. H_2O. In this range, and under field conditions, accurate impact pressure measurements are extremely difficult.

It is imperative that a rigid, vibrationless base be provided for the inclined manometer used in making these measurements. A slope of 20:1 or even greater is recommended for readings of this order. It may be found that occasional negative readings are obtained at particular locations in the stack. It is suggested that these be noted and that the upward velocity be assumed as zero at these places. It is not felt that velocity corrections based on stack gas composition (CO_2, CO, and H_2O content) are justified; velocities should be calculated based on air, and Orsat analyses for CO and CO_2 need be made only when the presence of these gases is important from a pollution standpoint.

Velocity profile determinations are not sufficient in themselves, changes in average velocity with time must be determined in order that the average discharge rate can be obtained. It is suggested that after having made five or six pitot traverses taken at various times during the charging cycle, a point which most nearly represents the average velocity in the stack be selected and measurements of changes in velocity with time be recorded for this location.

Concurrently with the pitot readings described previously, stack temperatures should be measured within two or three inches of the head of the pitot tube. These measurements are necessary in order to convert pitot tube readings into local stack velocities and these measurements must be taken simultaneously with the pitot readings since

temperature cycling amounting to 500°F and more can take place from one charge to the next.

Bare chromel-alumel thermocouples can be used for this service and these can be inserted into the cupola stack mounted within or upon appropriate supporting probes. For temporary or one-time application, ordinary steel pipe may be used, but for repeated use a stainless steel or inconel probe should be constructed. If temperatures above 1800–2000°F are encountered, water cooling of the probe may also be necessary.

It must be noted that the indicated temperatures of hot gas streams involve appreciable error because of the relative rates of heat transfer to and from the thermocouple junction. It is essential that at least a single radiation shield be used around the thermocouple junction and a triple-shielded junction is very much more to be preferred.[16, 17, 18, 19]

Having determined the average rate of discharge of the stack gases it becomes necessary to sample the particulate matter contained therein.[1, 2, 4, 6] Of prime importance is the selection of the filtering element for the sampling train. A variety of collectors are used for this purpose including paper or alundum filter thimbles, wet and dry impingers, and small, portable electrical precipitators. Most common are filter thimbles and impingers and each has relative advantages over the other. For cupola sampling is it believed that filter thimbles are the better choice. They yield a dry catch, the quantity of which is easily determined by direct weighing; they can be mounted directly on the sampling probe thereby shortening the length of tubing through which the sample must pass before it is collected, i.e., less probe to clean; being of all metal construction, they are generally more rugged, and they are appreciably more convenient to handle in the normally confined space of a sampling station since no liquid has to be transported or transferred.

The major objection, in many cases, to the use of dry filters is the occurrence of condensation in the sampling probe and on the filter surface itself. This will occur whenever the sampling stream cools below its dew point and when it does happen, continued sampling is very nearly impossible because of the high resistance to flow imposed by a wet filter or, in the case of paper thimbles, because of the rupture of the wet thimble. Alundum thimbles can be placed very close to a hot stack and are often placed inside the stack immediately adjacent to the sampling nozzle. When necessary this can be done, but extreme caution must be observed in order that thermal expansion of the thimble holder does not result in particulate leakage past the gasket seal at the neck of the thimble.

An additional disadvantage of this technique is the high temperature of the thimble holder upon removal from the stack and the consequent difficulty in disassembling the holder to remove the thimble. When paper thimbles can be used, they are to be preferred because they are considerably less fragile, they are cheaper and lighter in weight, and they have a much smaller resistance to flow than the alundum type.

Fortunately, it appears that the moisture content of cupola stack gas is quite low. In the current tests as well as in those reported by the Technical Sub-Committee of the Gray Iron Foundry Smog Committee,[20] no condensate was ever collected in water-cooled condensers included in the sampling trains used in both cases. This means that, with the danger of condensation absent, paper thimbles can be used for particulate collection so long as they are kept far enough from the stack to avoid charring temperatures (250–300°F). It has been found that for stack temperatures below 1000–1200°F and sampling rates on the order of one scfm, the thimble holder can be held within 15 to 20 in. of the stack wall. When stack temperatures are nearer 2000°F the thimble will char under these conditions. It appears that little difficulty should be experienced, however, in selecting a probe of sufficient length that this does not occur. Also because of the low humidity within the stack, a condenser should not normally be required in the sampling train.*

The question of isokinetic sampling is one of major importance. It has become almost a rule-of-thumb among those in the field that isokinetic conditions are essential in obtaining representative samples of particulates greater than roughly 10 microns in diameter. To be sure, isokinetic conditions are to be preferred where possible but all is not lost when isokineticism cannot be strictly adhered to.[21, 22, 23]

Figures 1, 4, and 5 of Appendix B illustrate the types of changes in stack conditions occurring continually during cupola operation. With a "null-type" nozzle in a high velocity (1000 fpm at 70°F, i.e., velocity head 0.06 in. H_2O), gas stream, such oscillations would be difficult to follow, but under conditions met within cupola stacks (at 1200°F a velocity of 1000 fpm produces a velocity head of only 0.02 in. H_2O), where one is below the satisfactory operating limits of the null-probe, attempts to follow such variations would be almost out of the question under field conditions. When conditions permit and a well trained sampling team is available the null method is preferable.

As a satisfactory substitute, it is recommended that both a pitot tube and a thermocouple probe be inserted into the stack in the immediate vicinity of the sampling probe. One operator should record stack temperatures and velocity pressures alternately at roughly 15-second intervals, while a second operator adjusts sampling rate as often as is convenient to the approximate average velocity calculated from the velocity and temperature readings given. Sampling rates are easily metered with a previously calibrated orifice flowmeter.

In practice, flow adjustments can be made at about 90-second intervals when velocity head tables and graphic or nomographic relationships between nozzle velocity, actual sampling rate, and standard volumetric flow rate are used.[24]

By basing each successive calculation on the average stack conditions up to that time, the average sampling velocity will normally approach rather closely the average stack velocity through the sampling period. As outlined by Hemeon and Haines,[22] the best estimate of the total particulate matter being discharged is obtained by ratioing the weight of particulate collected to the volume of gas equal to the "product of the nozzle area and the stack gas velocity approaching the nozzle (regardless of the velocity in the nozzle itself)."

An alternative procedure, which is strictly valid only when true isokinetic sampling has been accomplished, is to divide the weight of particulate matter collected by the actual volume of gas sampled. When this is to be done, it is convenient to use a totalizing volumetric meter in the sampling train. In either case, of course, the loading is more conveniently expressed when volumes are converted to some set of standard conditions.

The times, locations, and durations of sampling will be determined by the objectives of the sampling test under way. Since cupola firing practice involves several well-defined periods of operation (light-off, burning in, tapping, and final melt-down), data may be desired on emissions generated during any one or all of these periods. Also, information may be desired with respect to weight of particulates emitted, chemical analysis of these particles, particle sizes discharged, etc.

Whatever the objectives may be, the sampling team must base the procedures of its tests upon them. It is extremely important to recognize that tre-

* A typical sampling train will consist of: (*1*) sampling nozzle, (*2*) sampling probe, (*3*) paper thimble, (*4*) vacuum pump, (*5*) volumetric meter, and (*6*) orifice flowmeter.

mendous variations in the character and quantity of particulate matter discharged are possible from cupola to cupola and from one moment to the next in a single cupola. For example, a charge of dirty scrap followed by a clean charge can change the emissions as from night to day. Because of this, valid conclusions can never be based upon single observations and it is almost axiomatic that the more samples taken, the more meaningful are the results.

Appendix A

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Appendix B

Description of Sampling Expedition to a Foundry

In January 1959 arrangements were made to sample cupola emissions at a foundry.

Four cupolas have been installed at this foundry; three are of the conventional type (approximately five feet in diameter x 70 ft high), while the fourth, of the same size, is a newly installed, water-cooled cupola, the lower 15 or 20 ft of which is constructed of unlined boiler plate cooled externally by a flowing film of water. Each of the cupolas is topped by a cone-type gas washer through which water is recirculated continuously during cupola operation.

On the current schedule of operation, the water-cooled cupola is operated for about seven hours each day and one of the three conventional cupolas is operated for a two- or three-hour period each afternoon. The cupolas are of the hot-blast type and air-blast volumes are in the range of 3500–4000 scfm* per cupola.

After a 90-minute light-off and burning-in period, a cupola is tapped by inserting an oxygen lance through the tap hole and tapping is carried on continuously thereafter. Metal charges weighing about 1500 lb each are dropped into the cupolas through charging doors located about 30 ft above the cupola bottoms. The charging cycle averages about five minutes; but charges are fed at the discretion of the charges-crane operators with attempt to maintain a relatively constant tuyere pressure. Actual charging cycles range from about one minute to around 10 minutes on occasion.

Description of Tests

After setting up a sampling station at the charging door of the water-cooled cupola, measurements were made (using a five-foot, water-cooled, and triple-shielded chromel-alumel thermocouple) of the variation in stack temperature through several charging cycles. As would be expected, the minimum stack temperature occurs just after a fresh charge has been dropped and at this time temperatures fell as low as 600 to 700°F at the charging door.

Accompanying this low temperature were billowing clouds of dark gray smoke which persisted for only a matter of seconds and which undoubtedly contained a large percentage of mechanically formed dust of relatively large particle size (50 to 100 μ). After the charge, stack temperature increased rather rapidly to about 1000–1100°F and subsequently maintained a gradual increase up to between 1300° and 1400° F before the next charge was dropped.

Following these temperature measurements, some preliminary pitot readings were made at several positions in the stack to determine the range of manometer readings to be expected. At the charging door the cupola diameter is 57 in. and pitot readings (with a 10:1 slope Type C Micro-Manometer, E. Vernon Hill & Co.) were taken at the center-line as well as about one foot from both the near and far walls. Using a five-foot blunt-end pitot tube, a velocity pressure (vp) of 0.01 in. H_2O was obtained at the near wall, a vp fluctuating between 0.02 and 0.03 in. H_2O at the center-line, and readings varying between 0.03 and 0.05 in. H_2O at the maximum insertion.

By assuming a uniform stack temperature of 1000°F,† it is seen that the velocities sensed, based on average manometer readings, were 11, 18, and 22 ft/sec respectively. Velocity pressure measurements using a standard pitot tube were made at the same locations and the readings obtained were 0.015–0.035 in. H_2O at the near wall, 0.01–0.27 in. H_2O at the center-line, and *negative* values at the far wall. The averages of the readings obtained indicate velocities of 18 ft/sec at the near wall and 15 ft/sec at the center-line (based on a stack temperature of 1000°F).

The only conclusion to be drawn from the negative readings is that turbulence at that location resulted in the measurement of some impact pressure by the static taps or a reverse flow at that location actually was occurring. This latter possibility is certainly not out of the question and such a phenomenon could

* @ 70°F and 19.7 psi.

† During this exploratory expedition, temperature and pitot traverses were made at different times for convenience; in practice, they should be made concurrently and actual stack temperatures applied in making velocity calculations.

be caused by either thermal or mechanical baffling effects.

At this point a sampling train was set up consisting of (*1*) a $^1/_2$ in. stainless steel sampling nozzle, (*2*) a Western Precipitation Corporation stainless steel sampling probe, (*3*) a four-foot black iron probe extension, (*4*) an alundum filter thimble, (*5*) a PHS disc filter, (*6*) a condenser, (*7*) a Sprague dry meter, (*8*) an orifice meter, and (*9*) a Gast vacuum pump. A sampling velocity of 16 ft/sec (at 1000°F) was chosen (based on previous pitot measurements) requiring a sampling rate of 0.48 scfm.

At this rate and with ambient air flowing, the initial pressure drop across the disc filter was 0.25 in. H_2O while that across the thimble was 5.6 in. H_2O. When sampling was started, the thimble pressure drop increased to 11 in. H_2O in the first 15 sec. Since this threatened to blow the manometer metering, this differential sampling was stopped and manometer was disconnected.

It is possible that some of the pressure increase was due to increased gas viscosity at higher temperatures, but this is probably not a significant factor since the sampling probe remained cool to the touch within 15 to 20 inches of the stack wall during the entire subsequent five-minute sampling period. During this five-minute period a total of 2.5 scf was sampled as indicated by the Sprague dry gas meter. Three-quarters of a grain of dust was collected on the alundum thimble† indicating a stack loading of 0.3 grs/scf.

Unfortunately a slight amount of water from the manometer across the alundum thimble entered the sampling train and destroyed the possibility of determining alundum thimble filter efficiency by weighing dust catch on the disc filter. Of major significance here, however, is the fact that no condensate at all was collected in the water-cooled condenser.

By this time the conventional cupola was in operation and had been tapped out; it was decided to make preliminary temperature and stack velocity measurements at the charging door of this cupola. The temperature cycle observed (600 to 1200°F) was essentially the same as that described above but the pitot traverse (11, 33, and 11 ft/sec respectively) showed a higher centerline velocity than was found in the water-cooled cupola stack.

Returning to the sampling station at the water-cooled cupola a formal 12-point pitot traverse was made. The velocity measurements obtained

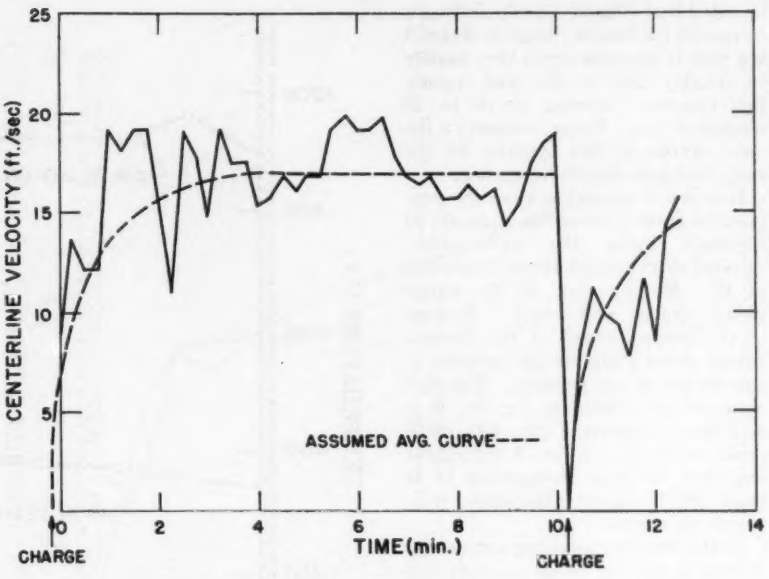

Fig. 1. Cupola stack velocity changes with time (at charging door).

increased consistently from 0 ft/sec at $1^1/_8$ in. from the near wall to 21 ft/sec at $1^1/_8$ in. from the far wall. (Again, velocities are based upon an assumed temperature of 1000°F.) The average velocity was 13 ft/sec which is equivalent to a discharge rate of 5000 scfm.

During the light-up period on Thursday, February 12, the center-line temperature of the water-cooled cupola at the charging door was measured with a dual iron-constantan bare thermocouple probe. Both couples produced identical readings of 830°F. This temperature is unquestionably much lower than the actual gas temperature since no radiation shields existed around either couple.

After the water-cooled cupola had been tapped out, a series of measurements was made at the center-line to determine changes in stack velocity with time. The micro-manometer was adjusted to a 20:1 slope and this considerably increased the ease with which readings could be made. Since no concurrent temperature measurements were made, a constant temperature of 1000°F was assumed in making the velocity calculations. Velocity variations are shown in Fig. 1. It should

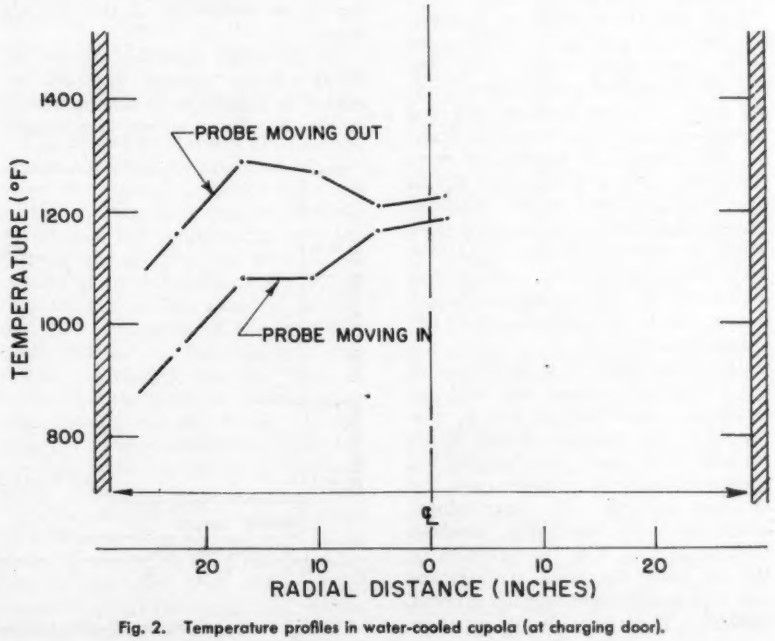

Fig. 2. Temperature profiles in water-cooled cupola (at charging door).

† It is felt that weighing thimbles to closer than one mg is not justified; use of a control thimble to correct for humidity changes as discussed in reference (1) is recommended.

be noted that effluent velocity decreases to zero at the time a charge is dropped but that it increases again very rapidly to roughly half of its peak values, this increase occurring in 10 to 20 seconds or less. It may require on the order of two to four minutes for the peak discharge rates to be reached.

It is also of interest to know the temperature profiles across the diameter of cupolas. Using the water-cooled, shielded thermocouple, several traverses at the charging door of the water-cooled cupola were made. Because of the limited length of the thermocouple probe available, an insertion of only 30 inches was possible. The data obtained are plotted in Fig. 2. It is seen that a gradient of some 200–300°F exists across the radius of the cupola and that, as well, fluctuations of at least 200°F occur practically from minute to minute.

At this time the sampling station was shifted to the top of the conventional cupola to take advantage of the time during which this cupola was to be operated. All samples and other measurements were taken through a three-inch diameter sampling port located approximately six feet below the top of the cupola and at least two feet below the annular drain pan for the cone-washer.

Several temperature profiles were measured with the water-cooled probe. The first of these was taken just at the end of the melt-down period and the latter two were measured during the tapping out operation while the air blast was off. These data are presented in Fig. 3. With the air blast off, only a very small gradient (60 to 70°F) exists between the cupola wall and the center-line of the stack.

Even with the air blast on, however, the maximum gradient is of this same order, contrasting sharply with the 200–300°F gradient noted at the charging door. Caution must be observed throughout this entire report in drawing any generalized conclusions from the limited data available, but, in this case, the apparently smaller temperature gradient above the charging door would be expected because of (*1*) the lower stack temperature, and (*2*) the higher velocity and increased turbulent mixing due to the influent air at the charging door itself.

The temperature cycle at the top of the conventional cupola was next determined. It is shown in Fig. 4. For the first five minutes during which readings were made, the tapping out operation was being completed and the air blast was off. The temperatures measured were essentially constant (295 ± 25°F). With the initiation of the air blast the stack temperature rose very rapidly to an average of about 1600°F. The dropping of the first

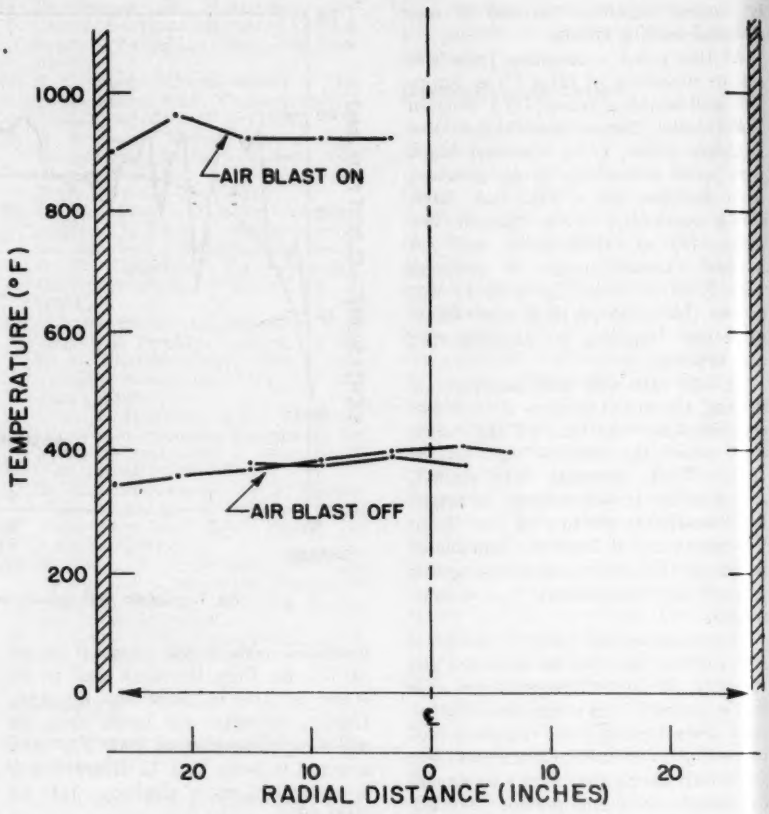

Fig. 3. Temperature profiles near top of conventional cupola.

charge produced no significant cooling but the second charge after tapping out lowered the outlet stack temperature by some 300°F. This is still appreciably less than that observed at the charging door (~600°F) and is undoubtedly a result of thermal damping by the influent air at the charging door.

At the upper sampling station, effluent velocity readings were also recorded as a function of time as shown in Fig. 5. These curves demonstrate the same cyclic characteristics noted at the charging door with the distinction that velocity does not fall to zero at the time of charging but rather maintains a high "background" level as a result of the flow of air in through the charging door.

To determine the velocity profiles existing at the top of the cupola two 12-point pitot traverses were made across the diameter of the stack; each profile required between three and four minute and a five minute interval

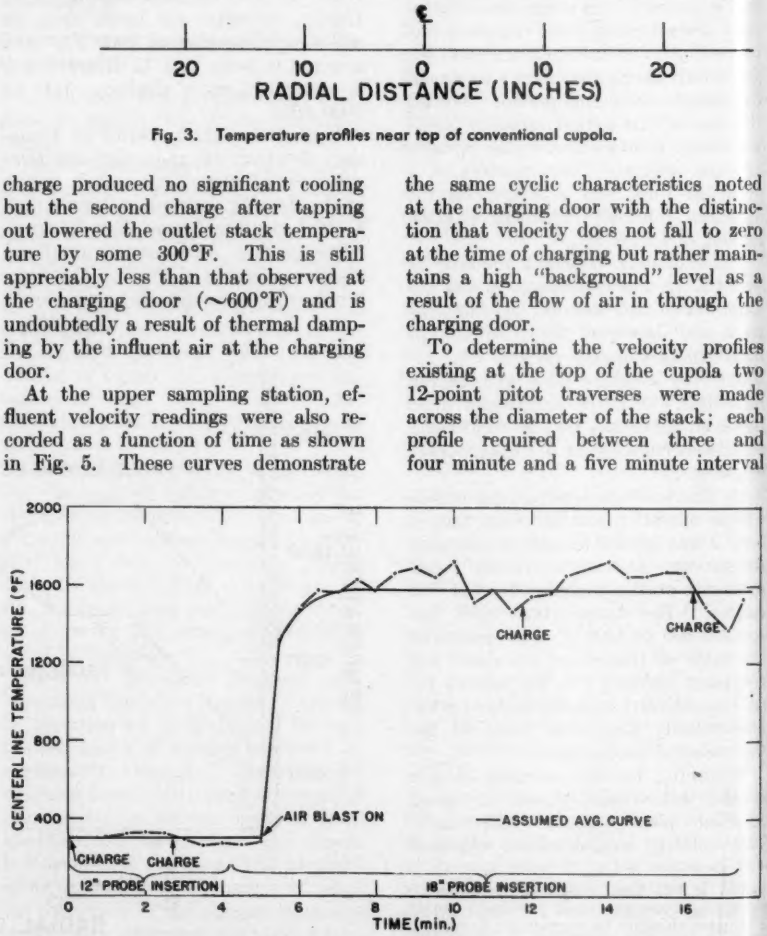

Fig. 4. Cupola stack temperature changes with time.

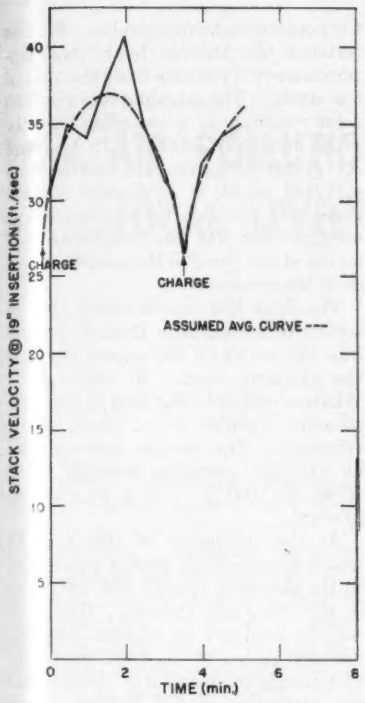

Fig. 5. Cupola stack velocity changes with time (near top of stack).

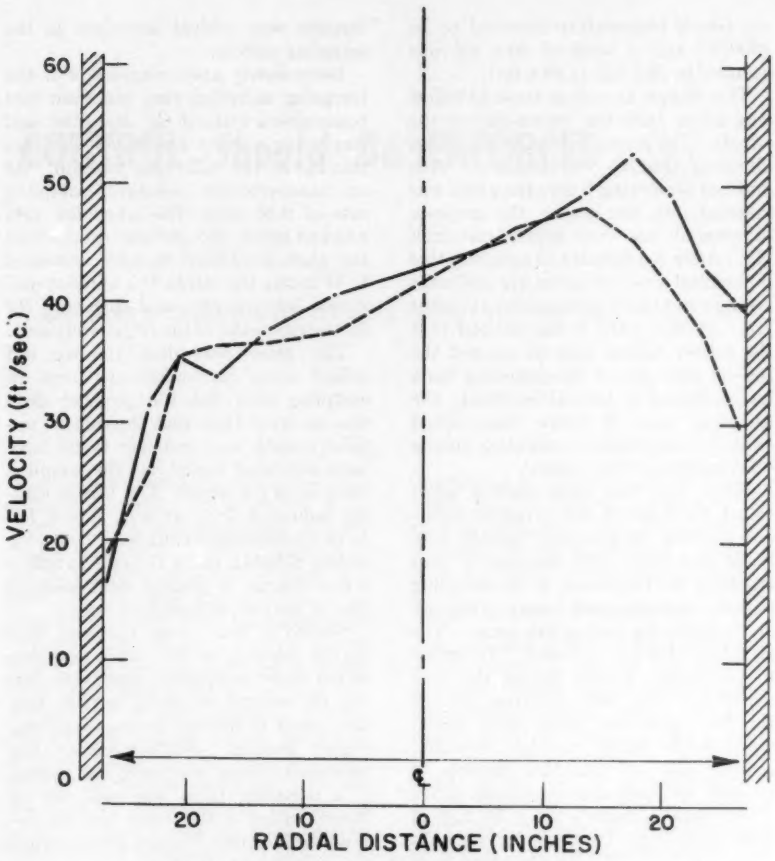

Fig. 6. Velocity profiles near top of conventional cupola.

was allowed between the two traverses. The results are shown in Fig. 6. The profiles are both skewed toward the far wall of the stack which is also the opposite wall from the charging door below. The skewed profile is undoubtedly inherent in cupola stacks above the charging door.

The reproducibility shown by the two profiles is quite good especially when one considers that about eight or nine minutes elapsed between readings of corresponding points on the two profiles. The average velocities from the two profiles were 40 and 37 ft/sec respectively and these correspond to discharge volumes of 10,300 and 9400 scfm if a temperature of 1500°F is assumed for the stack.

The remainder of the tests conducted concerned particulate sampling from the cupolas. First, a sample was taken at the sampling station located near the top of the conventional cupola. The sampling train was identical to that described previously. The sample was collected at a $19^1/_2$ in. insertion distance at a sampling velocity, based on the previous pitot traverse, of 38 ft/sec (assuming almost 44 ft/sec) giving a total volume sampled of 13.8 scf. A sampling time of 15 minutes was employed to cover roughly three charging cycles.

The primary objectives of this test were to measure the collection efficiency of the alundum thimble in the sampling train and to determine whether condensation of moisture would occur in the probes or on the thimble. The answers to both of these questions were those hoped for; no discoloration of the disc filter was an indication of essentially 100% efficiency of collection by the alundum thimble and, more importantly, no condensation whatsoever was detected in the probe, on either filter, or even in the water-cooled condenser itself. The stack loading determined by this test was 0.06 gr/scf.

Encouraged by the lack of condensation in the previous sample it was decided to attempt a sample collection within a Whatman paper thimble. In this case the sampling train was the same as the previous one with the exception of the substitution of a Whatman thimble for the alundum thimble and the elimination of the four foot probe extension. The sampling conditions established were the same as before and the resultant average sampling velocity was 39.5 ft/sec. In this case, 8.3 scf were sampled in 10 minutes. Because of the removal of the four-foot probe extension from the train, the Whatman thimble holder was only about 18 to 20 inches from the wall of the stack. Even before the start of this sampling test it was noted that charging had ceased and that the cupola had entered the final melt-down period.

As a consequence, stack temperature began to increase quite appreciably and by the end of the 10-minute sampling period, stack temperature was at least above 2000°F (a foundry engineer estimated the temperature to be between 2300° and 2400°F). When the probe was withdrawn, the thimble was found to have charred on its outer surface (possibly due to radiant heat transfer directly to the thimble holder rather than to the temperature of the sampled gas). The thimble had actually lost weight (65 mg) and 40 mg of material had been collected on the disc filter. This 40 mg may have been composed of particulate from the stack or it may well have been composed, at least in part, of combustion residue from the Whatman thimble.

On the morning of the following day, the sampling station was relocated at the charging door of the water-cooled cupola. The first test at this point was multi-purposed; these purposes being (*1*) to determine the pressure drop across an alundum filter thimble, (*2*) to compare this drop with that across a glass wool-packed alundum thimble, (*3*) to check the collection efficiency of an alundum thimble on cupola fume, and (*4*) to again verify the absence of condensate within the sampling train. The sampling velocity used was 35 ft/

sec (stack temperature assumed to be 1000°F) and a total of 30.6 scf was sampled in 29.5 min (1.04 scfm).

This sample as well as those to follow was taken from the center-line of the cupola. The pressure drop across a clean alundum thimble was measured with ambient air flowing before the probe was inserted into the stack; the pressure differential was very nearly one inch Hg. After 1.5 minutes of sampling this differential was 1.6 inches Hg and after two minutes had it increased to 11 inches Hg. At this point it was noticed that the rubber tubing used to connect the several elements of the sampling train had collapsed in several locations; the sampling was, therefore, interrupted while heavier-walled connecting tubing was installed in the system.

When flow was again started, additional readings of the pressure differential across the alundum thimble were made and these held practically constant for the remainder of the sampling period, varying only from $14^{3}/_{4}$ to $16^{1}/_{4}$ inches Hg during this time. The alundum thimble collected 1.71 grains of particulate matter during this test while the disc filter backing up the thimble collected only 0.03 grain. On a weight basis, therefore, it would appear that an alundum thimble is roughly 98% efficient on cupola fume. These data indicate a stack loading of 0.06 grain/scf. Once again, no condensate was evident anywhere in the sampling system.

Immediately upon completion of the foregoing sampling run, the train was reassembled without the disc filter and employing a glass wool-filled alundum thimble as the collecting medium. At an inadvertently obtained sampling rate of 0.55 scfm (the scheduled rate was one scfm), the pressure drop across the glass wool-filled thimble increased to 16 inches Hg within $1^{1}/_{2}$ minutes and varied between $14^{3}/_{4}$ and 16 inches Hg for the remainder of the $13^{1}/_{2}$ minute test.

The glass wool-filled thimble did collect more particulate per unit of sampling time but the pressure drop was no lower than that through an unfilled thimble and probably would have been somewhat higher had the sampling rates been the same. The higher loading indicated (0.15 gr/scf) is not felt to be attributable in any way to the collection thimble, but is thought to reflect a true change in average stack loadings during the two sampling periods.

Should it have been the case that higher fraction of the catch was collected under subkinetic conditions during the second sampling period, this, too, could contribute to an apparently higher loading. No condensate was produced during this sampling period.

A sampling train was next set up incorporating a Whatman thimble behind the four-foot Western Precipitation Corporation sampling probe. In this instance the thimble holder was approximately 18 inches from the wall of the stack. The sampling rate was 0.80 scfm resulting in a sampling velocity of 38 ft/sec at 1000°F. In this test 5.1 grains of particulate matter were collected which is equivalent to 0.68 grain/scf. No charring of the thimble occurred nor was any condensate observed at any point in the sampling train or in the condenser.

The final test run involved the insertion of an alundum thimble directly into the center of the cupola stack at the charging door. In this case a Whatman thimble was used to back the alundum thimble for a check of its efficiency. The sample was collected at 1.6 scfm (sampling velocity — 76 ft/sec at 1000°F) over a $6^{1}/_{2}$ minute interval.

At the conclusion of this test 5.5 grains of particulate matter were found in the alundum thimble and 5.0 grains in the Whatman thimble. There was definite evidence of leakage past the asbestos gasket at the open end of the alundum thimble and it is obvious that the expansion of the thimble holder along with the high pressure differential across the thimble combined to result in gross leakage past the alundum thimble. Based upon the total catch in both thimbles, a loading of 1.0 gr/scf was calculated.

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Why AIR POLLUTION CONTROL *Should Be* ENFORCED *at a* LOCAL LEVEL*

CHARLES E. COUCHMAN, Baltimore Health Department, Baltimore, Maryland

Before presenting the conspectus that air pollution control enforcement should be at a local level of government, it is felt that a significant prefacing observation should be made. The four panel papers on local vs state enforcement programs represent a cross-section of viewpoints by authors who are vitally interested in different aspects of air pollution control. It is necessary to assume that before there could be any differences of opinion among them as to where an enforcement program should be centralized, the participants must have previously agreed and accepted that an enforcement program is necessary. This, alone, is a milestone in the field of air pollution control. It was not too many years ago when certain interests advocated that air pollution enforcement programs need not be vested in a government agency but contended that the potential offenders could very well police themselves. Indeed, the agreement of the panelists on the necessity for a governmental enforced program is in itself a major accomplishment which overshadows the issues to be discussed here today.

Local Economic Advantages

One of the chief considerations for the continued survival and sound growth of any program is economy. This truism does not exclude an air pollution enforcement program regardless of its administrative level in either local or state governments. The objective of this paper is to demonstrate that at the local level an air pollution enforcement program is more economical and is in a favorable position to render its services more promptly to the citizens. It is hardly necessary to point out the obvious savings realized merely by comparing the distances traveled in a city or a county with those in a state. The same reasoning applies equally to communication costs. These are two items which are of a tangible nature and are readily assessable. More important is the factor of time which is more difficult to evaluate and can only be assessed depending upon the magnitudes of the services required by any event. It is known that air pollution episodes have very wide limits as to their importance. A few became critical and their emergency nature called for services comparable to those required to contain a conflagration. Wisdom has dictated that a service responding to an emergency, such as a fire department, should be established at a local, and never at a state, level. It is not unrealistic to make this type of comparison when one is reminded of episodes which have occurred in Donora,[1] Poza Rica,[2] and the Muese Valley.[3] These unfortunate events involved much more than economic consideration. It is now conceivable that the administration of an air pollution enforcement program at a local governmental level could effectively avert or at least ameliorate such catastrophies. It is well to emphasize at this juncture the apparent dissimilarity of the contaminants involved in these three instances cited. Furthermore, it is the evidence collected in such investigations which ably supports the widely accepted belief that conditions responsible for air pollution differ considerably depending upon topography, meteorology, and the kinds and amounts of emissions into the atmosphere from man's activities.[4]

In order to obtain the greatest yield for the money expended, an air pollution program should be directed toward the specific sources of air pollution in a particular community. In general, a concerted effort toward a single objective is more rewarding than attacking a problem on a broad front. This is particularly true of air pollution problems because of their varied nature. Invariably, it is always more economical to control a problem at its source rather than to allow it to become generalized. This philosophy approaches the old axiom that "an ounce of prevention is worth a pound of cure."

Origin of Local Enforcement

As a matter of fact, at least one phase of air pollution control has been effectively handled on a local enforcement basis over a period of many years. It is only necessary to mention the outstanding records of accomplishments in the field of smoke control in many cities especially in Pittsburgh and St. Louis. Smoke control enforcement on a local basis has been the established pattern and a successful one in this country. It could be well emulated in other fields of air pollution control.

One of the likely reasons for the success of the enforcement program in smoke control is that the ordinances governing this type of activity invariably require that plans for fuel burning equipment or other smoke producing operations be submitted to the local official agency before the desired work can be started. In this way, the agency is able to insist upon incorporation of control measures on operations which may otherwise be sources of smoke emissions. This same approach has been used successfully on a local basis where other types of air pollution are encountered.[5, 6] Needless to say, it is unlikely that a state agency for the control of air pollution is in a position to review effectively plans for operations and processes which are likely to be performed in many communities within its boundaries.

Another basic reason for advocating local, instead of state, enforcement on air pollution control is that the different types of pollution encountered in a state are usually just as varied as the industrial composition of its many communities. As a practical example, a one-industry town would certainly be more justified in tolerating levels of pollution from such a source than if the

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22-26, 1960, Cincinnati, Ohio.

offender were located in a large metropolis and in close proximity to other types of industries emitting contaminants. In the latter case, one or more of the other contaminants might have a synergistic effect whereby the composite atmosphere would be intolerable.

Still another prime reason for local preference over state control of air pollution is that it should be the desire of the people in a particular community to regulate the quality of air they wish to breathe. This desire is often stimulated by alert public officials[7] and sympathetic press support as exemplified by the bi-weekly compilation of newspaper clippings appearing in the *Smog News*.[8] At times, because of emotional factors, an unreasonable situation is created to the detriment of the entire community. In such instances, a well functioning state or federal agency could be of material assistance in resolving differences at the local level at least to the partial satisfaction of all. A state agency could also be of help to a local unit if an offending source of air pollution were located outside of the corporate limits of the community affected.

Present and Future Local Programs

At the present time, air pollution programs have been related to the control of contaminants normally emitted from the burning of fuels or from industrial operations. For the most part, the fuels have been those which are used for the prime purpose of generating heat. Only more recently has one enlightened agency passed legislation dealing with the consumption of fuels for motivation where exhaust gases from automobile engines are believed to be a prime cause of air pollution in that area.[9]

With the increased attention being given to the effects of air pollution, there is a correspondingly growing awareness of the implications it has upon health. It is a natural tendency, therefore, for air pollution programs to be gravitating towards health agencies. In any event, where the activity is carried on in some other agency, it is a good practice for that agency to work closely with the local health department because any cause and effect health relationship is apt to be more demonstrable and more readily observed.

Some of the other phases of air pollution which are presently being explored or appear to be on the horizon, but not normally associated with any operating agencies enforcing legislation on air pollution control, are the fall-out of radioactive particles placed in the atmosphere by man and air contamination from natural causes. The significance of natural pollutants upon the health of man cannot be overemphasized.[10] For example, within the very recent past it has been clearly demonstrated that tuberculosis organisms have been readily disseminated within the atmosphere of hospitals and that, in all likelihood, the current staphylococcus infections in a number of hospitals are of the air-borne nature. There has been a tendency for the workers in this field to disassociate the subject from air pollution by labeling it "air hygiene." A few private and public agencies have also been interested in another natural contaminant; namely, the pollens. Here again, the unfavorable effects are not materially different from certain air-borne dusts which cause allergic reactions. Fortunately, all particulate matter, regardless of origin, follows a set pattern in the ability to separate and collect it from air by physical means. Basically, many of the engineering principles underlying the control of air pollutants are adaptable to these problems without major modification. As these other types of activities receive more public support, it is only sensible, then, that programs involving all airborne substances be incorporated in one agency similar to a water pollution control agency which also involves many separate disciplines such as chemistry, engineering, physics, and bacteriology. For the present it appears that such a consolidated agency for controlling all forms of air pollution should be operated at a local level. As more experience is gained, it may be desirable to re-evaluate this viewpoint.

Conclusions and Summary

Experience gained by smoke control agencies, which were the first engaged in air pollution control, proved that effective progress was made when operations were conducted on a local enforcement basis. A major reason for this initial and continued success was the requirement that plans, incorporating control measures, had to be acted upon before installations were made. A similar requirement is very effective in the control of chemical pollution of the atmosphere. Experience has also shown that legislative control, directed at specific sources of air pollutants, is more economical and more effective when enforced at a local rather than at a state level.

It is also advocated that the control of all types of air pollution, including radioactivity and those from natural sources, should be consolidated in a single agency operating, preferably, on a local basis, with the state functioning in an advisory capacity to the local communities. On the other hand, the state should assist in bringing about relief from an air pollution source located outside of a local enforcement area.

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Welcome New Members

(Continued from p. 156)

Fort, W. R.
Bartow, Fla.

Gillette, L. A.
Wyandotte, Mich.

Godfrey, Robert W.
Torrance, Calif.

Hainsworth, William R.
Los Angeles, Calif.

Hammond, George A.
North Attelboro, Mass.

Harris, Bruce
Los Angeles, Calif.

Hauser, E. N.
Elgin, Ill.

Heck, Walter W.
College Station, Tex.

Hendrix, Houston W.
Devon, Pa.

Flint, Leslie L.
Minneapolis, Minn.

Heyer, Robin S.
San Bernardino, Calif.

Holland, Roy T.
Erie, Pa.

Hudson, Warner
Chicago, Ill.

Hunter, W. G.
Toronto, Ontario, Canada

Jensen, Donald A.
Berkeley, Calif.

Jerome, H. M.
Toronto, Ontario, Canada

Johnston, Donald R.
Cincinnati, Ohio

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The HEALTHY *Environment**

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U. S. Public Health Service, Department of Health, Education, and Welfare

The fact that the APCA organization had its beginning more than half a century ago stamps its founders as real pioneers—men who were thinking about conservation at a time when the general emphasis was still on exploitation of every resource in sight. There are indications that even now those groups which are genuinely interested in conservation are on the pioneering fringe of our society. They are to be congratulated for perseverance in pursuing a long and sometimes thankless quest.

While browsing through a compendium edited by Dr. Harlow Shapley which has as its laudable purpose the education of scientists in sciences other than their own, I noted in his introduction, Dr. Shapley traces the slow but sure swing of scientific thought from a man-centered world to a galacto-centered universe. All of us have been sharply aware, in recent years, of the tremendous emphasis on the macrocosm and the microcosm—on outer space, and the space inside the atom. We cannot help but be fascinated and awed by the work of James Van Allen, the discoverer of the belts of radiation around the earth. Here we see—to borrow a phrase from Dr. Don Platt of the University of Chicago—a man stepping to the door of his planet to see how the temperature is outside.

But with all this probing of outer space and piercing of inner space, we tend to neglect the mundane, prosaic middleground in which we live and breathe. As a matter of cold, hard fact, we are closer to putting a man on the moon than we are to creating a thoroughly healthy and pleasant environment on this earth for man to live in—closer in know-how, closer in time, closer in probability of achievement.

A visitor from another planet might find this one of the most perplexing features of our perplexing world—unless, of course, he had become a space visitor because he could no longer tolerate the air on his own planet.

Clearly there is an imbalance here, between the progress of certain physical sciences and the progress in what is essentially an economic and social endeavor—the protection of the public health against our own pollution. I am going to suggest this afternoon that one fundamental reason for this imbalance lies in the fact that the atomic scientists and the space scientists are relatively unencumbered by old traditions, old shibboleths, old ways of doing things which are no longer applicable.

My keynote is that we who are interested in the conservation of man—and everyone here today is in the public health business, whether we call it that or not—will have to reopen our books, scratch out some of the old texts we have lived by, and write in some brand new materials which are keyed to the problems of today rather than those of yesterday.

We who are directly involved in the administration of public health are presently going through this kind of agonizing reappraisal. And agonizing it is—the old order changeth, giving place to the new, but reluctantly. Many of us in the so-called health professions would be much happier, and all of us would be much more comfortable, if we could go on forever working confidently and successfully on relatively simple, tidy problems like the control of such communicable diseases as typhoid fever, malaria, and the venereal infections. But, while these jobs are never quite done, we are being forced by circumstances beyond our control into the strange, complex, and mysterious world of chronic diseases and toxic environmental hazards. The frontiers of health have moved, and we must move with them.

I suspect, although I do not have enough first-hand experience with your work to know for certain, that your organization, with its 53-year tradition rooted in the relatively simple, tidy problem of smoke abatement, may need the same sort of agonizing reappraisal. Newly developed knowledge may not fit comfortably into old theories. For example, I would expect that some of your members may have been startled by the occurrence of beryllium lung disease associated with community air pollution. Also, Haagen-Smit's pioneering work, I am sure, is having profound effects on the outlook of those of you concerned with the practical application of air pollution control measures.

Similarly, one of the most significant differences between 1907 and 1960 thinking has been acceptance of the idea that economic growth can be accelerated by planned research and development. Accordingly, expenditures for industrial research and development have been expanding impressively, but research activities on the attendant health hazards have not expanded proportionately.

On the assumption, therefore, that your need for re-orientation of thinking is somewhat parallel to ours, it might be helpful if I were to outline for you briefly the nature of the transition in public health, as we in the Public Health Service see it today.

As you know, environmental health activities until World War II were concerned primarily with communicable diseases. Public health efforts contributed largely to the banishment from many parts of the world of such once-dreaded epidemic diseases as typhoid fever, cholera, malaria, yellow fever, and typhus. Similarly, the incidence of the dysenteries and other filth-borne diseases was greatly reduced by environmental control. Health activities designed to curb the biological agents of disease were completely interwoven into our everyday lives, in our structure of government services, in our economic system—so well and so thoroughly that they were, and are taken for granted by the average citizen. In short, chaos was turned into order through the application of scientific knowledge and co-operative effort on the part of all segments of society concerned. A relationship favorable to

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good health was achieved between man and his biological environment.

But the triple onslaught of population growth, accelerated urbanization, and what amounts to a new industrial revolution has tipped the scales again. Our dazzling technological progress since World War II has yielded a random harvest of mixed blessings, and a bumper crop of new health challenges. These challenges differ from our traditional health concerns in a number of significant ways.

For one thing, the nature of the assault on the human organism is very different. The public and the health professions are familiar with the infectious disease pattern—exposure, followed at a predictable interval by recognizable symptoms, generally followed by recovery and some degree of residual immunity. The time-span between exposure and onset is short. The effect is comparatively easy to trace to its cause.

By contrast, the chronic diseases may have multiple causes, some intrinsic but often involving one or many environmental factors. We are concerned here, not primarily with acute illness but with the slow accumulation of toxic chemicals or radiations over a period of years. The symptoms which finally develop may be identical with those resulting from nonenvironmental causes; radiation-induced leukemia, for example, shows no detectable difference from leukemia unrelated to radiation exposure. For these reasons, absolute proof of cause is difficult to establish within the limits of our present knowledge. And yet there is abundant evidence, both from the laboratory and from epidemiological studies, which indicates that a relationship must exist. The hazard to the individual seems to be related to the cumulative total of radiations or chemical toxicants received continuously or intermittently throughout his life span, regardless of their source.

A second way in which our new concerns differ from our old ones has to do with the complexity of the political, social, and administrative structure within which we must seek and apply solutions. Traditionally, the responsibility for environmental health protection has rested with the level of government closest to the people. The local community, aided as necessary by the state, has been the first line of defense.

But the growth of the metropolis has greatly complicated the structure of local government and its relation to the state. The New York metropolis, to take the largest but by no means the only example, is an organic part of 22 counties in three different states. Within this area there are more than 1400 separate political jurisdictions. Many of these separate jurisdictions separately circulate their traffic, build their schools, obtain fresh water, dispose of sewage, clear their slums, and put out their fires. How successful will they be in dealing individually with the darkening air mass that they share in common?

Another example can be found in the Ohio River Valley, not far upstream from where we are this afternoon, where one of the most seriously polluted community air supplies in the region blankets a town with no significant pollution source at all. It owes its shroud to its larger neighbors; the citizens of this unhappy community couldn't improve their situation no matter how eager they might be to do so.

Finally, the most basic difference of all between the traditional and the contemporary environmental health challenges lies in the nature of our goals. It isn't as open and shut to be in favor of health as it used to be. The malaria mosquito and the typhoid bacillus have no friends. Their presence does nobody good. When these are our enemies, we can go all out. We can aim for total eradication.

But when we are dealing with the possible harmful effects of the by-products of our industrialized society, our goal is not conquest but containment. Plainly, Americans have made it clear that they want a metropolitanized, industrialized world. What we must recognize is that it would be the height of folly to create this shining new world for a human race whose health has been seriously impaired in the process. In defining progress, we must take into account the biological limitations of the human species. And while those limitations are still imperfectly understood, it behooves us to err on the side of caution. In short, we must seek a balance which permits maximum development at minimum hazard.

The *New Yorker Magazine*, during the past year or so, has published a column from time to time entitled "These Precious Days," and subtitled "A fever chart of the planet earth, recording Man's ups and downs in contaminating the air, sea, and soil." Generally it has recorded more downs than ups—although the most recent column, a couple of weeks ago, did note the new California legislation on motor vehicle exhausts.

There is, of course, a plainly discernible twist of ironic humor in the *New Yorker's* treatment of the subject. But let us not be deceived. Beneath that humor lies a profound concern which is shared, not just by cranks and calamity howlers but by thoughtful citizens whose number grows with every passing day. The American people are becoming increasingly disturbed about the pollution of their surroundings, and their concern increases in proportion to their knowledge. We in the Public Health Service have little difficulty in detecting this trend.

We get letters about air pollution—hundreds of them, from big cities and from such unlikely places as Waxahatchie, Texas and Orono, Maine. A year and a half ago, just after the National Conference on Air Pollution, we thought that the flood of mail would dwindle off as soon as the interest in the Conference subsided. On the contrary, it has continued at the flood stage.

We see newspaper clippings, also from communities both large and small, and from nearly every state. These include editorials, cartoons, and letters to the editor, as well as straight news stories. Their general tenor is "Let's do something about it."

All of you are aware, of course, that many of the leading general circulation magazines have published articles on air pollution within the past two years.

Citizens' groups, ranging all the way from the General Federation of Women's Clubs to the American Municipal Association, have endorsed the need for greater emphasis on air pollution research and control.

In the Public Health Service we are also feeling the swelling tide of interest at the highest governmental levels. A little more than a year ago, Mr. Fogarty's Subcommittee of the House Committee on Appropriations requested the service to make a "thorough study of the environmental health problems and the most efficient organization of our facilities to meet these needs." Our report, in the preparation of which we received great assistance from consultants outside government, was then discussed in an unprecedented two-day hearing this spring. Partly as a result of this study, the Public Health Service is presently undertaking a major reorganization, one of whose principal features will be increased stature and prominence for our environmental programs including, of course, air pollution.

Also, as you know, legislative proposals of the administration have been introduced in both Houses of Congress to provide permanent authority for the present federal program, to remove the existing $5,000,000 limitation on annual appropriations, and to authorize the holding of public hearings on air pollution problems which are of broad, national significance or interstate in character. These proposals, combined with existing legislation, would provide the Department of Health, Education, and Welfare with authority needed to carry out those activities which are presently deemed desirable, including the conduct and support of research, technical assistance to state and local agencies, training of personnel, demonstration projects, financial aid when appropriate, and the conduct of public

hearings on important problems of interstate character or national significance.

As a final and conclusive indication that air pollution has arrived as a major subject of national concern, Surgeon General Burney was asked to present a discussion of the air pollution problem to the president and his cabinet on April 8 of this year. These command performances are rather rare for the Public Health Service. This one, judging by what Dr. Burney told me afterwards, was received with close attention, and elicited a number of questions demonstrating keen interest in the subject on the part of those present.

In summary, then, your association is dealing with a hot subject. The high degree of interest which it now enjoys should be a tremendous asset to you. This public concern will permit, and demand, a far higher degree of activity than could be achieved before air pollution attained its present prominence.

Since the closing day of the National Conference in 1958, there have been many heartening indications of increased activity and progress. Valuable information on levels of air pollution throughout the nation has been made available through the co-operative activities of local, state, and federal authorities in the National Air Sampling Network. We have begun to assess the quantities of individual pollutants present in the atmosphere. A recent paper on benzpyrene levels, written by Dr. Sawicki and other scientists of the Sanitary Engineering Center in Cincinnati, is an example. The State of California has taken unprecedented steps toward the control of air pollution. It has established the first state-wide health standards for pollutants in community atmosphere in this country. The development of control devices for automobiles has been accelerated, and such devices will soon be available for use.

It appears that industry is accepting more responsibility for the control of air pollution from its operations. Available data indicate a national expenditure by industry of over $300,000,000 for this purpose. But within industry the extent of voluntary acceptance of this responsibility is quite variable. And although procedures and equipment are now available for the control of many emissions, their application and use are far from universal.

Examination of state and local activity in the field furnishes evidence that our co-operative march toward a solution is halting, and the columns irregular. The Public Health Service, in co-operation with the Conference of State Sanitary Engineers, has developed information showing that the total state expenditures for 1960 for air pollution was about $1,600,000 throughout the country. California accounted for about half of the total sum. Only six other states spend as much as $50,000 per year on air pollution. With few exceptions, programs at the local level are still inadequately financed and staffed to do a comprehensive technical and enforcement job under today's complex conditions.

Lack of adequate activities at the state and local level where control responsibility rests can nullify much of the progress made elsewhere. Twenty-three of our metropolitan areas are interstate, and many more will be in the near future. On the whole, we are not much closer to taking effective action against interstate air pollution problems than we were 53 years ago.

If the picture I have painted seems unjustifiably gloomy, it may be a reflection of my general feeling of urgency in regard to the environmental problems which confront all of us. We need to meet the challenges of this inspiring and frightening time with resources scaled to the magnitude of the problems, and with imagination proportionate to the creative vigor which has brought us to this condition.

Scientific endeavor is a creative process, and perhaps the fact that a degree of chaos normally accompanies creation helps to explain the unevenness and irregularity of our progress toward achieving the goal to which our nation is dedicated—the shaping of an environment which satisfies man, his needs and desires to the fullest possible extent. We can blame the vagaries of the creative process if we do not learn what we need to know in the proper order. But we can only blame ourselves if we fail to bring a needed degree of order into chaos by applying what we know at the proper time and in the proper places.

To say, as some people still do, that we cannot afford to control environmental pollution within safe limits is patently absurd. If there is money enough to develop 7000 new products each year, there is money enough in the richest nation in the world to control their by-product wastes. If there is money enough for motivational research to find out why people buy a product, there is money enough to make sure they are not injured by its existence.

Moreover, the eyes of the world are upon us as never before. The nations of the world which exist side by side with us in space are seeking to catch up with us in time, and in decades they are spanning centuries. They have looked to us for answers to their infectious disease problems, and we have not been found wanting. How will we fare when they want assistance in industrialization without contamination?

In conclusion, I repeat that we are all in the public health business. The basic decisions affecting our health are being made, and will be made, by people without professional health training. They are economic and social decisions. But they must be made in the context, literally, of the facts of life. Those of us to whom public health is the primary consideration of our professional lives welcome and depend upon the co-operation of those of you whose work, though ostensibly in other fields, is inextricably interwoven with ours. All of us are, in John Donne's phrase, involved in mankind.

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EXHAUST COMPOSITION *in Relation to Fuel Composition**

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The early classic studies by Haagen-Smit[1, 2] demonstrated that the characteristic manifestations of the smog prevailing in the Los Angeles Basin were due to photochemically activated atmospheric reactions involving hydrocarbons, oxides of nitrogen, and sunlight. He showed further the effect of hydrocarbon structure in the reaction and found olefinic compounds to be the most reactive. The prime sources of the hydrocarbon pollution were determined by the Los Angeles Air Pollution Control District surveys to be local refinery and vehicle exhaust emissions. Process controls installed by petroleum companies have substantially reduced hydrocarbon emissions from the refineries, leaving the automobile as the major source of pollution.

Mader[3, 4] in his search for means of reducing or eliminating auto exhaust as a source of pollution attacked the problem at the fuel level. By spectrographic analysis he showed a quantitative association of certain olefin compounds in both fuels and exhausts obtained from these fuels. In further experiments he also found that as the olefin content of the fuel was increased, there occurred a similar increase in experimental smog manifestations.

With the advent of gas chromatography as an analytical tool, several laboratories made use of this procedure to more closely investigate the relationship between fuel and exhaust composition. Hurn[5, 6] and his co-workers at the Bureau of Mines showed by G.L.P.C. analysis that the exhaust composition is influenced by both fuel composition and engine variables. From these studies he concluded that nonolefinic fuels produce significant quantities of olefins but that the olefinic concentration in exhaust emissions generally increases above this quantity as the olefin content of the fuel increases, at least through the 40% olefinic level.

Schuck, Ford, and Stephens[7] reported as a result of studies sponsored by the Air Pollution Foundation that the concentrations of hydrocarbons in vehicle exhaust are determined by engine operation while the relative quantities of individual hydrocarbons are determined by fuel composition. They also report that if cracked products are excluded, the relative concentrations of individual hydrocarbons are approximately the same in both fuels and the exhausts produced.

The exhausts produced by the various fuels in these studies were also irradiated in an environmental chamber. From these tests they found that the pentenes, butenes, and butadiene were nearly consumed after two hours of irradiation; propene proved to be slightly less reactive; and only half of the ethylene reacted. Upon examination of the concentration of individual hydrocarbons in the exhaust, a high correlation was found between eye irritation and the concentrations of certain C_4 and C_5 olefins. These olefins were butadiene, cis and trans-2-butene, and the pentenes. Unsaturates which did not correlate well with eye irritation were 1-butene, isobutylene, ethylene, acetylene, methyl acetylene, propylene, and propadiene. Eye irritation did not correlate with the concentration of any of the saturates measured.

Heaton and Wentworth[8] gave further evidence of the fuel-exhaust relationship by analyzing both the parent fuel and its exhaust. They concluded from their work that "with about 40% of the exhaust hydrocarbons composed of fuel components, it appears that the hydrocarbon composition can be influenced by proper selection of the components comprising the gasoline."

With the foregoing evidence in hand the Los Angeles County Air Pollution Control District took before the County Board of Supervisors the proposal to limit the olefin content of gasolines marketed in Los Angeles County. This was approved and the following limits read into the law: that no gasoline will be marketed with a Bromine Number higher than 30 by July 1, 1960, and by January 1, 1962, the Bromine Number may not exceed 20.

The Board of Supervisors also requested that a Joint Program be set up between the Air Pollution Control District, the Western Oil and Gas Association, and other interested governmental agencies, to explore further the relationship between fuel composition and smog manifestations. The following paper is the result of the first phase of this program.

Experimental

Production of Exhaust Gas Samples

In previous studies the total hydro-

Table I—Operating Conditions of Gas Chromatograph

Variables	1st Stage	2nd Stage	3rd Stage
Column support	Fisher "Column-Pak"	Fisher "Column-Pak"	Fisher "Column-Pak"
Column substrate	Polypropylene glycol (MW-400), 20 wt %	Polypropylene glycol (MW-400), 20 wt %	Polypropylene glycol (MW-400), plus B,B′ oxydipropionitrile, 20 wt %
Column length, ft	15	20	10-PPG + 3-OPN
Column temp., °C	85	45	40
Helium flow,[a] ml/min	72	64	63
Inlet pressure, psig	34	24	11
Theoretical plates[b]	1061	3072	3147
Detector, type	Thermistor	Thermistor	Thermistor
Sensitivity,[b] M.V. ml/mg	2122	4358	4347

[a] At column temperature and ambient pressure.
[b] Reference: *n*-Pentane.

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22-26, 1960, Cincinnati, Ohio.

Table II—Fuel Specifications[a]

	Fuel No. 1	Fuel No. 2	Fuel No. 3	Fuel No. 5	Fuel No. 2A	Fuel No. 2P
Properties:						
Gravity, API	57.1	56.3	56.0	56.5	44.1	70.2
RVP, lb	9.5	9.3	9.3	9.4	9.2	9.5
Distillation, °F						
Initial	91	94	92	95	93	91
5% Rec	111	117	115	113	116	114
10	124	130	128	125	131	130
20	147	150	148	144	160	157
30	168	170	170	163	192	184
40	189	193	192	188	223	210
50	214	218	218	213	250	232
60	242	245	242	240	278	258
70	271	272	271	265	301	282
80	297	298	299	293	315	301
90	329	327	329	324	325	319
95	359	358	356	355	331	331
End point	401	404	406	400	345	346
Recovery, vol %	97.5	98	98	97.5	97.5	97.5
Sulfur, total, wt %	0.01	0.01	0.013	0.042	0.017	0.011
Sulfur, RSH, ppm	0.0004	0.0001	0.0002	0.0004	0.0001	0.0005
Gum, existent, mg/100 ml	0.3	0.03	1.1	2.3	5.6	0.6
Gum, accelerated, 4 hr, mg/100 ml	1.0	1.1	1.4	3.2	11.9	1.1
Bromine No. (electrometric), g/100 g	11	20	31	49	19	20
TEL, ml/gal	0.99	0.87	0.53	1.38	0.02	1.35
FIA (as received)						
Saturates, vol %	59.0	54.2	47.1	38.8	20.0	88.0
Olefins, vol %	4.2	8.2	13.9	22.9	8.1	9.6
Aromatics, vol %	36.8	37.6	39.0	38.3	71.9	2.4
Octane No.						
Motor, F-2	91.0	90.3	88.9	87.9	89.1	95.0
Research, F-2	100.1	100.3	100.1	100.1	101.9	99.5

[a] All data were obtained from the Western Oil and Gas Association.

carbon emission of a vehicle during road operation has, by necessity, been determined by the analysis of grab samples representing each of the four major driving cycles. The analytical results from each driving cycle then had to be proportioned to previously determined traffic and driving pattern surveys to arrive at a calculated value for the total hydrocarbon emission of a vehicle. It is unlikely that this approach was capable of adequately taking into consideration all of the transient operating conditions that occur during road operation of a vehicle.

To overcome these limitations a proportionate sampling system was used in this present study.[9] This system was designed to continuously meter and accumulate a constant percentage of exhaust gas discharged from a vehicle.

The sampling rate of this device varied simultaneously with the exhaust gas flow rate. This was accomplished by an electronic system consisting essentially of a strain gage pressure transducer, voltage amplifier, and a power amplifier. The latter operated a servovalve which controlled the flow to a three cu ft accumulator tank. The control signal to the system was obtained by the use of a viscous flowmeter which metered the air delivered to the carburetor of the vehicle.

All exhaust gas samples analyzed were produced by a 1956 six-cylinder Chevrolet operating under traffic conditions. The route over which the vehicle traveled was so planned as to represent the conditions experienced during normal traffic in a metropolitan area. The route was 28.5 miles in length and required approximately one hour's driving time.

Analytical Instrumentation

In the analysis of both fuels and exhaust a three-stage gas chromatograph was used. It consisted of two model 1A "Chromat-O-Flex" analyzers, used in the first two stages, and a model 11 "Chromat-O-Flex" in the third stage. These instruments were purchased from Loe Engineering Company, Pasadena, California. They were connected in series by lengths of staging tubes. Pertinent operational data are listed in Table I.

Due to the long elution time of aromatics under these conditions, a single stage was equipped with an eight ft column of B, B′ oxydipropionitrile at a temperature of 87°C and a helium flow of 80 ml/min. These operating conditions resulted in the C_3-C_{10} olefin-paraffin compounds being completely eluted before benzene. The aromatic compounds may then be analyzed in a reasonable length of time.

Table III—Carbon Balance Calculated for Fuels (Liq Vol Percent)

Fuel No.	1	2	3	5	2A	2P
Saturates	56.5	56.1	47.0	42.8	23.8	81.9
Olefins	5.2	10.0	16.9	22.8	9.2	10.7
Aromatics	36.8	37.0	37.5	32.5	70.0	1.7
Total recovered	98.5	103.1	101.4	98.1	103.0	94.3

Analytical Procedures

A. Fuels

The six fuels were analyzed by injecting samples of appropriate volume into the instrument. This method of introduction eliminated the possible loss of light ends by prior treatment. Additional analyses were performed after treatment of the fuels with benzene sulfenyl chloride.[10] This procedure removes olefins as high boiling end products and enables resolution of mixed olefin-paraffin peaks thus permitting unequivocal identification. Using peaks known to be due to paraffins alone, ratios were calculated for the decrease in peak area of mixed peaks and proper adjustments were made in the quantitative data.

B. Exhaust Gases

The exhaust gas sample was transferred directly from the accumulator tank into a stainless steel 500 ml cylinder. The cylinder was then attached to a gas sample handling system which contained small tubes of Ascarite and magnesium perchlorate for the removal of water and carbon dioxide (these compounds in no known way interfere with or change any of the hydrocarbon compounds present in exhaust gases) and a freeze-out trap consisting of an eight inch column of polypropylene glycol (20 wt %) on Fisher "Column-Pak." The column was immersed in liquid oxygen. The exhaust contents were then transferred from the stainless steel cylinder into the freeze-out trap where all hydrocarbon compounds were retained with the exception of methane. Proper valve adjustments were made and the sample introduced into the chromatograph. The liquid oxygen flask was removed from the freeze-out trap and the trap immersed in a flask of warm water, thus allowing the hydrocarbon compounds present to be flashed into the first stage column.

G.L.P.C. Analyses of Fuels

The six fuels used in this investigation were special blends prepared for the co-ordinated study by member refineries of the Western Oil and Gas Association. Properties of the gasolines are listed in Table II. The more typical marketed

fuels 1, 2, 3, and 5 had (by FIA analysis) different olefin-paraffin concentrations with the aromatic fractions remaining approximately constant. In these gasolines the olefin content increased with fuel number, while the paraffins decreased in proportion to the olefinic increase. In the two special fuels, 2A and 2P, the olefin content remained at approximately the same level as fuel 2, while the paraffin-aromatic concentrations were varied to yield a high paraffinic fuel 2P and a high aromatic fuel 2A. These were specially blended in order to determine what effect a highly aromatic or a highly paraffinic fuel would have on their respective exhaust gas compositions.

Comparison of the qualitative results obtained on the treated and untreated fuels revealed that in fuels 1, 2, and 3 the bulk of the olefins was in the C_5-C_6 range. In fuel 5 approximately 20% of the olefins in the olefin fractions were heptenes with the C_5-C_6 olefin concentrations being slightly greater than found in fuel 3. The olefin content of fuels 2A and 2P approximated that found in fuel 2. From these observations it can be inferred that the olefins in fuels 1, 2, 3, 2A, and 2P were obtained from light catalytically-cracked stocks while fuel 5 was blended with a quantity of a different catalytically-cracked stock.

In the C_7-C_9 olefin and paraffin groups qualitative identification was uncertain. Therefore, the compounds were grouped in general classes according to carbon number.

Carbon balances of each of the fuels were made from the known charge introduced into the gas chromatograph and the hydrocarbons recovered. The results show a range of 94 to 103 volume percent as recovered (Table III). This was within the expected G.L.P.C. accuracy of ±5%. As the carbon balance recoveries were close to the theoretical of 100 volume percent, all results were normalized so as to achieve an equal basis. To facilitate comparison of fuel-exhaust gas data all normalized volume percent data were converted to mol percent. These results are given in Table IV.

G.L.P.C. Analysis of Exhaust Gases

Triplicate road tests and analyses were made on each of the fuels. In the G.L.P.C. analyses, hydrocarbon compounds with a molecular weight greater than the C_7 paraffins and the C_6 olefins were not included due to the uncertainty of the qualitative identification of the C_8-C_{10} portions of the exhaust. Analyses of the entire aromatic fraction of the exhaust gases were not completed due to interference of trace quantities of water; therefore, only benzene and toluene could be determined.

Table IV—Fuel Analysis by Gas Chromatography (Mol Percent)

Fuel No.	1	2	3	5	2A	2P
Component						
Olefins						
1-Butene + Isobutylene	t[a]	t	t	0.5	0.2	0.2
trans-2-Butene	t	t	t	0.6	t	t
cis-2-Butene	t	t	t	0.6	t	t
1-Pentene	0.1	0.3	0.4	0.8	0.3	0.3
2-Methyl-1-butene	0.5	0.8	1.5	1.9	0.7	0.9
trans-2-Pentene	0.5	1.1	1.8	2.1	0.8	1.1
cis-2-Pentene	0.3	0.5	0.8	1.2	0.4	0.6
2-Methyl-2-butene	1.6	2.8	4.3	5.3	2.0	2.9
4-Methyl-1-pentene	t	0.2	0.3	0.3	0.3	0.3
cis-4-Methyl-2-pentene	t	t	0.7	0.5	0.5	1.0
trans-4-Methyl-2-pentene	t	t	0.3	0.5	0.3	0.7
1-Hexene / 2-Methyl-1-pentene	0.4	0.6	1.0	1.1	0.5	0.8
cis-3-Hexene / 2-Ethyl-1-butene / trans-2-Hexene	0.7	0.7	1.5	1.4	0.7	1.4
cis-2-Hexene	0.4	0.5	1.2	1.4	0.5	1.1
Cyclopentene	0.1	0.3	0.4	0.3	0.3	0.4
Unidentified hexenes	0.7	1.2	2.5	2.1	0.6	0.8
Unidentified heptenes	0.3	0.7	1.4	4.6	0.7	0.8
Total olefins	5.6	9.7	18.1	25.2	8.8	13.3
Total butenes	t	t	t	1.7	0.2	0.2
Total pentenes	3.1	5.3	9.2	11.6	4.5	6.2
Total hexenes	2.2	3.2	7.5	7.3	3.4	6.1
Total heptenes	0.3	0.7	1.4	4.6	0.7	0.8
Paraffins						
Ethane	t	t	t	t	t	t
Propane	t	t	t	t	t	t
Isobutane	1.0	0.8	0.8	0.6	0.6	1.2
n-Butane	9.8	8.5	8.7	6.2	7.8	12.7
Isopentane	8.3	8.6	7.9	8.6	9.3	9.8
n-Pentane	2.3	2.3	2.2	2.3	0.9[b]	0.8
2,2-Dimethyl butane	0.9	0.6	0.2	0.2	—	—
2-Methyl pentane / 2,3-Dimethyl butane	11.4	8.5	4.9	3.1	0.8	5.1
3-Methyl pentane	3.9	3.2	1.7	1.2	—	—
n-Hexane	1.4	1.5	1.5	1.3	0.2	0.3
2,4-Dimethyl pentane	1.6	1.8	1.7	1.1	0.2	5.4
2-Methyl hexane	1.1	1.2	1.6	1.4	0.2	0.5
3-Methyl hexane / 2,3-Dimethyl pentane	3.7	4.0	3.2	2.6	1.1	7.9
n-Heptane	1.4	1.3	0.8	1.9	—	—
2,2,4-Trimethyl pentane	1.7	1.8	1.6	0.8	0.3	7.5
n-Octane	0.4	0.6	0.6	1.0	—	—
Unidentified heptanes	0.1	0.4	—	0.4	—	0.1
Unidentified octanes	4.3	5.2	5.5	4.6	1.0	10.8
Unidentified nonanes	0.5	0.9	0.2	0.2	—	21.2
Total	54.3	51.1	43.1	37.5	22.4	83.3
Naphthanes						
Cyclopentane	1.3	1.1	0.9	0.8	0.4	0.6
Methyl cyclopentane	0.5	0.9	0.7	1.4	0.5	0.8
Cyclohexane	0.3	0.5	0.1	0.3	0.1	—
Total	2.1	2.5	1.7	2.5	1.0	1.4
Total butanes	10.8	9.3	9.5	6.8	8.4	13.9
Total pentanes	12.4	12.0	11.0	11.7	10.6	11.2
Total hexanes	18.4	15.2	9.1	7.5	1.6	6.2
Total heptanes	7.9	8.7	7.3	7.4	1.5	13.9
Total octanes	6.4	7.6	7.7	6.4	1.3	18.3
Total nonanes	0.5	0.9	0.2	0.2	—	21.2
Aromatics						
Benzene	2.7	1.8	2.0	1.7	21.8	0.1
Toluene	10.2	9.4	9.3	9.0	12.5	0.2
Ethyl benzene	1.2	2.2	2.2	1.9	1.1	0.1
m-Xylene / *p*-Xylene	7.3	7.2	7.2	6.5	5.2	0.6
Isopropylbenzene	0.6	0.2	0.4	0.4	0.2	t
n-Propylbenzene / *o*-Xylene	3.6	3.3	3.6	3.1	3.2	0.5
1,3,5-Trimethylbenzene + other C_9 or C_{10} Aromatics	1.0	1.1	0.9	0.8	3.4	t
n-Butylbenzene / 1,2,4-Trimethylbenzene + other C_9 or C_{10} Aromatics	4.1	4.4	4.1	4.1	11.7	—
Unidentified C_9 or C_{10} aromatics	7.3	7.0	7.4	7.3	8.8	0.5
Total	38.0	36.6	37.1	34.8	67.9	2.0
Summary						
Saturates	56.4	53.7	44.8	40.0	23.4	84.7
Olefins	5.6	9.7	18.1	25.2	8.7	13.3
Aromatics	38.0	36.6	37.1	34.8	67.9	2.0

[a] t = trace; less than 0.05 mol %.
[b] — = not found on chart, may be present in small concentrations.

Table V—G.L.P.C. Analysis of Exhaust Gases (Ppm by Volume)

Fuel Number	1				2				3				5				2A				2P			
Run Number	1	2	3	Av	1	2	3	Av	1	2	3	Av	1	2	3	Av	1	2	3	Av	1	2	3	Av
Olefins																								
Ethylene (1)	254	254	241	250	257	243	250	250	229	238	250	239	255	245	231	244	128	125	122	125	391	364	363	373
Propene	88	93	95	92	88	82	97	89	77	76	78	77	78	81	69	76	28	32	37	32	148	137	158	148
1-Butene + Isobutylene	28	28	29	28	30	29	27	29	29	29	30	29	28	31	29	29	11	10	10	10	89	85	82	85
trans-2-Butene	3	3	4	3	4	4	4	4	5	5	2	4	7	8	9	8	2	2	2	2	9	10	9	9
cis-2-Butene	2	2	2	2	2	5	3	3	3	4	2	3	5	7	7	6	2	1	3	2	8	8	7	8
3-Methyl-1-butene	—	—	—	—	—	5	4	3	5	4	t	3	7	7	4	6	2	—	—	1	11	12	5	9
1-Pentene	2	2	2	2	3	2	2	2	3	3	4	3	4	5	5	5	1	1	1	1	2	2	2	2
2-Methyl-1-butene	4	4	5	4	8	6	6	7	10	11	12	11	11	10	15	12	4	3	4	4	9	8	8	8
trans-2-Pentene	4	4	4	4	8	6	6	7	10	13	10	11	12	12	14	13	4	4	4	4	6	5	6	6
cis-2-Pentene	2	2	2	2	4	3	3	3	5	7	5	6	6	6	7	6	2	2	2	2	3	3	3	3
2-Methyl-2-butene	9	9	12	10	21	13	15	16	27	31	29	29	27	31	33	30	9	9	9	9	18	18	18	18
4-Methyl-1-pentene	—	—	—	—	—	—	—	—	2	7	3	4	2	3	1	2	2	1	1	1	4	3	1	3
1-Hexene + 2-methyl-1-pentene	3	2	2	2	6	4	4	5	7	8	9	8	5	6	6	6	3	2	2	2	3	3	4	3
trans-2-Hexene + cis-3-Hexene + 2-Ethyl-1-butene	4	3	2	3	8	8	8	8	8	9	15	11	9	12	11	11	3	3	3	3	10	7	11	9
cis-2-Hexene	3	3	3	3	5	4	4	4	6	7	9	7	6	6	7	6	2	3	2	2	5	4	5	5
Unidentified hexene	3	3	3	3	7	5	6	6	7	9	10	9	7	12	9	9	3	3	3	3	6	5	6	6
Cyclopentene	1	1	1	1	2	1	2	2	2	3	2	2	3	2	2	2	2	4	2	3	4	3	2	3
Total	410	413	407	409	453	420	441	438	435	464	470	456	472	484	459	471	208	205	207	206	726	677	690	698
Total butenes	33	33	35	33	36	38	34	36	37	38	34	36	40	46	45	43	15	13	15	14	106	103	98	102
Total pentenes	22	22	26	23	46	36	38	40	62	72	62	65	70	73	80	74	24	23	22	24	53	51	44	49
Total hexenes	13	11	10	11	26	21	22	23	30	40	46	39	29	39	34	34	13	12	11	11	28	22	27	26
Diolefins																								
Propadiene	4	4	5	4	5	3	3	4	8	5	5	6	12	14	4	10	5	3	3	4	8	8	6	7
1,3-Butadiene	7	5	2	5	3	9	4	5	13	6	11	10	3	4	2	3	5	1	7	4	17	10	7	11
Total	11	9	7	9	8	12	7	9	21	11	16	16	15	18	6	13	10	4	10	8	25	18	13	18
Acetylenes																								
Acetylene	268	288	312	289	243	293	282	273	227	222	239	229	275	302	216	264	184	164	167	172	312	283	260	285
Methyl acetylene	7	9	10	9	9	12	11	11	10	11	8	10	13	13	12	13	9	7	9	8	17	18	20	18
Total	275	297	322	298	252	305	293	284	237	233	247	239	288	315	228	277	193	171	176	180	329	301	280	303
Paraffins																								
Propane	1	1	1	1	1	1	1	1	1	1	2	1	1	2	1	1	1	1	1	1	2	2	2	2
Isobutane	6	6	7	6	9	6	4	6	6	6	8	7	5	4	5	5	4	4	4	4	7	6	6	6
n-Butane	63	63	75	67	92	49	53	65	61	67	88	72	39	41	45	42	45	43	44	44	63	62	54	60
Isopentane	58	55	71	61	74	47	48	56	54	57	61	57	53	57	59	56	52	50	51	51	49	47	46	47
n-Pentane	18	16	21	18	20	13	15	16	16	17	19	17	13	13	15	14	5	5	5	5	3	3	3	3
2,2-Dimethyl butane	6	6	9	7	6	3	1	3	2	—	3	2	—	1	—	1	—	—	—	—	—	—	—	—
2-Methyl pentane + 2,3-Dimethyl butane	73	70	93	79	72	45	47	55	33	38	37	36	22	21	21	21	6	10	5	7	27	25	24	25
3-Methyl pentane	19	22	32	24	23	17	18	19	15	19	17	17	11	11	12	11	—	—	—	—	—	—	—	—
n-Hexane	7	8	12	9	11	8	8	9	10	12	11	11	8	10	11	10	1	1	2	1	2	2	2	2
2,4-Dimethyl pentane	4	12	16	11	8	8	13	10	8	9	15	11	8	8	11	9	1	t	1	1	31	30	31	31
2-Methyl hexane	7	6	9	7	10	10	6	9	7	8	9	8	8	9	10	9	t	t	1	1	2	3	2	2
2,3-Dimethyl pentane + 3-Methyl hexane	24	22	31	26	33	21	22	25	26	26	24	25	18	10	18	15	t	t	1	1	36	36	34	35
n-Heptane	8	7	8	8	10	6	8	8	12	19	16	16	NV	NV	13	13	t	t	t	1	3	3	3	3
2,2,4-Trimethyl pentane	10	11	13	11	15	8	10	11	11	20	11	14	6	8	7	7	t	t	t	1	34	36	35	35
Total	304	305	398	335	384	242	254	293	262	299	321	294	192	197	228	214	115	114	115	118	259	255	242	251
Naphthenes																								
Cyclopentane	5	8	12	8	10	6	5	7	5	9	5	6	3	11	5	6	2	4	2	3	4	3	2	3
Methyl cyclopentane	6	5	7	6	11	8	8	9	13	13	16	14	12	11	15	13	5	4	5	5	7	6	7	7
Cyclohexane	3	5	12	7	16	2	11	10	NV	15	3	9	1	—	3	1	t	t	1	1	0	3	0	1
Total	14	18	31	21	37	16	24	26	18	37	24	29	16	22	23	20	7	8	8	9	11	12	9	11
Total saturates	318	323	429	356	421	258	278	319	280	336	345	323	208	219	251	234	122	122	123	127	270	267	251	262
Total butanes	69	69	82	73	101	55	57	71	67	73	96	79	44	45	50	47	49	47	48	48	70	68	60	66
Total pentanes	81	79	104	87	104	66	68	79	75	83	85	80	69	83	79	76	59	59	58	59	56	53	51	53
Total hexanes	114	116	165	132	139	83	93	105	73	97	87	89	54	54	62	57	12	15	13	14	36	36	33	35
Total heptanes	43	47	64	52	61	45	49	52	53	62	64	60	34	27	52	46	1	t	3	4	72	72	70	71
Aromatics																								
Benzene	40	41	33	38	47	53	45	48	42	43	NV	43	44	49	42	45	202	201	205	203	9	5	8	2
Toluene	11[a]	92	85	89	99	44[a]	94	97	77	98	NV	88	85	94	85	88	NV	95	123	109	15	NV	NV	17
Total	NV	133	118	127	146	NV	139	145	119	141	NV	131	129	143	127	133	NV	296	328	312	24	NV	NV	25

(1) = May include small quantities of ethane.
— = Not found on chart, may be present in small quantities.
t = Trace; less than 0.5 ppm.
[a] Result not included in average.
NV = No value—compound was not determined.

In the analysis of exhaust gases two minor assumptions had to be made. The first was due to trans-2-pentene and 2,2-dimethyl butane being resolved on the same peak. Since their quantitative ratios had been determined in the fuels by the benzene sulfenyl chloride method, it seemed reasonable to assume that the same ratio could be applied to the exhaust gas analysis. The second assumption pertained to the determination of the unidentified hexene peak. This peak was observed in the chromatograms of both fuels and exhausts. When the fuels were reacted with benzene sulfenyl chloride the peak disappeared entirely. The identification was based upon this effect, as well as its retention volume being in the known hexene range.

A true measure of the original 1,3-butadiene content of the exhaust gases is not known due to its rapid reaction in the presence of oxides of nitrogen in

the exhaust. It was found that the butadiene concentration was halved when the exhaust samples were allowed to stand for one hour. As the driving route of the test car consumed approximately one hour the 1,3-butadiene is being depleted during the sample collection. Therefore, its true concentration is probably considerably higher than shown.

The analytical accuracy on the exhaust analysis is estimated to be ±5%. Results of analysis are given in Table V.

As the total hydrocarbon output of the exhaust emission could not be determined from G.L.P.C. analysis, a calculated "total" exhaust emission was made. The calculated emission was determined in the following manner: with the aid of the fuel analysis, the total concentration of unburned fuel in the exhaust was determined after first calculating the fraction X, not recovered in the exhaust gas analysis. The hydrocarbon concentration recovered in the exhaust was then corrected by this factor to give the total hydrocarbon concentration in the exhaust gases due to unchanged fuel. This quantity was then added to the concentration of the cracked products to give a "total" hydrocarbon emission. (The cracked products were assumed to be any hydrocarbon present in the exhaust and absent in the parent fuel. All calculations are on a methane-free basis.)

To estimate the percent hydrocarbons determined in the exhaust gas analysis, the hydrocarbon concentration recovered was divided by the calculated "total" exhaust emission. This reflects a recovery of 75–87% (methane excluded). The ratio of cracked products to the total hydrocarbon emission was also calculated. The results are given in Table VI.

As the data presented in Table VI were obtained using assumptions which have not been proved, they were not used in the following discussions of fuel-exhaust relationships.

Fuel-Exhaust Relationships

General

Hydrocarbon compounds found to be present in the exhaust gases, but not in the fuels, were ethylene, propene, propadiene, 1,3-butadiene, acetylene, and methyl acetylene. These compounds, together with isobutylene, 1-butene, trans-2-butene, cis-2-butene, and 3-methyl-1-butene which were found in trace amounts only in the parent fuel, comprise the major portion of cracked hydrocarbons in the exhaust gases. The balance of the compounds found in the exhaust gases were closely related quantitatively and qualitatively to their respective fuels. This relationship is shown in Figs. 1, 2, and 3. The increase of the C_5-C_6 olefins in the fuel and the corresponding increase in their exhaust gases is demonstrated in Fig. 1. The varying of the aromatic-paraffinic concentration of the fuels is also reflected in the exhaust as shown in Figs. 2 and 3.

The relationship of the olefins recovered in the exhaust gas samples to the olefins found in their parent fuels is shown in Fig. 4. The graph shows that the low molecular weight olefins (C_2-C_4) resulting from cracking in the engine do not vary significantly as the olefin content of the fuel is varied. There is a very definite variance, however, when the standard fuels 1, 2, 3, and 5 are compared to the special fuels 2A and 2P. The higher molecular weight olefins (C_5-C_6) in the exhaust gases are shown to vary proportionally with the respective olefin content in fuels 1, 2, 3, 5, and 2P; fuel 2A does not follow this trend but shows a value approximately 50% lower.

In Fig. 5 typical olefin, paraffin, and aromatic compounds are normalized with respect to the isopentane concentration found in the particular fuel or exhaust gas sample and their relative concentrations plotted. Isopentane was selected as the common denominator due to its concentration being the most consistent in the six fuels studied. The plotted ratios revealed a close correlation between fuel and exhaust. This may be interpreted as showing that the greater preponderance of C_4 paraffins and C_5 and higher boiling paraffins and olefins present in the exhaust gases were due to unburned fuel with a small percentage at most due to cracking processes.

The correlation between fuel and exhaust did not apply with regard to two aromatic compounds, benzene and toluene. In these two instances there were indications that these compounds were present in greater concentrations in the exhaust than in the parent fuel. The reason for this apparent increase is not known. It may be that benzene and toluene were not consumed as readily as the paraffin and olefin compounds or that these aromatic compounds were being synthesized in the engine. When benzene-toluene ratios were compared in the fuels 1, 2, 3, and 5 it was noted the benzene concentration was approximately five times greater than toluene. This same ratio was not reflected in the exhaust produced from these fuels. In fuels 2A and 2P this ratio was approximately the same in the fuels as well as the exhaust gases. In future investigations the relationship between aromatics in the fuel and exhaust will be more thoroughly studied.

Effect of Increased Olefin Content in Fuel

In fuels 1, 2, 3, and 5 the olefin fraction was progressively increased from a bromine number of 10 in fuel 1 to 50 in fuel 5. As the olefin fraction was increased, the exhaust gases produced from the fuels reflected no major change in the ethylene concentration in the exhaust; a slight but not significant decrease in propene; a small increase in butenes; and a marked increase in the C_5-C_6 olefins fraction in the fuels. (Figs. 1 and 4.)

There appeared to be no significant change in the acetylene or diolefin content of the exhaust gas as the olefin content of the fuel was increased.

Effect of Increased Paraffin Content in Fuel

In fuel 2P the paraffinic content was increased to approximately 85 mol percent with the olefin content remaining in the range of fuel 2. The analyses of the exhausts produced by this fuel revealed a large increase in the ethylene concentration when compared with fuel 2. This increase was also realized in the C_3 and C_4 olefins. The C_5-C_6 olefin concentration remained at relatively the same level as found in fuel 2. It was noticed that while ethylene and propene increase approximately one and a half times when compared with fuel 2, the butenes increased almost threefold (Fig. 4).

Table VI—Calculated Total Exhaust Emissions

Fuel Number	1	2	3	5	2A	2P
Percent of fuel hydrocarbons determined in exhaust analysis, mol %	68.8	66.3	65.5	64.1	64.0	63.7
Hydrocarbons recovered in exhaust analysis, ppm	1199	1195	1165	1128	833	1303
Cracked components in exhaust analysis, ppm	682	671	610	659	360	953
Raw fuel components in exhaust, ppm	517	524	555	469	473	350
Calculated concentration of raw fuel components not recovered in exhaust, ppm	234	266	292	262	266	199
Calculated total exhaust concentration, ppm	1433	1461	1457	1390	1099	1502
Percent of exhaust gas components recovered[a]	83.7	81.8	80.0	81.2	75.8	86.8
Percent of cracked components to calculated "total" hydrocarbons	47.6	45.9	41.9	47.4	32.	63.4

[a] Methane-free basis.

C4 - C6 PARAFFINS IN EXHAUST VS FUEL
C4 - C6 Paraffins in Exhaust, ppm (Vol.)
C4 - C6 Paraffins in Fuel, mol percent
0
50
100
150
200
250
300
0
10
20
30
40
1
2
2A
2P
3
5

Fig. 2.

C5 - C6 OLEFINS IN EXHAUST VS FUEL
C5 - C6 Olefins in Exhaust, ppm (Vol.)
C5 - C6 Olefins in Fuel, mol percent
0
25
50
75
100
125
150
0
5
10
15
20
1
2
2A
2P
3
5

Fig. 1.

BENZENE-TOLUENE IN EXHAUST VS FUEL

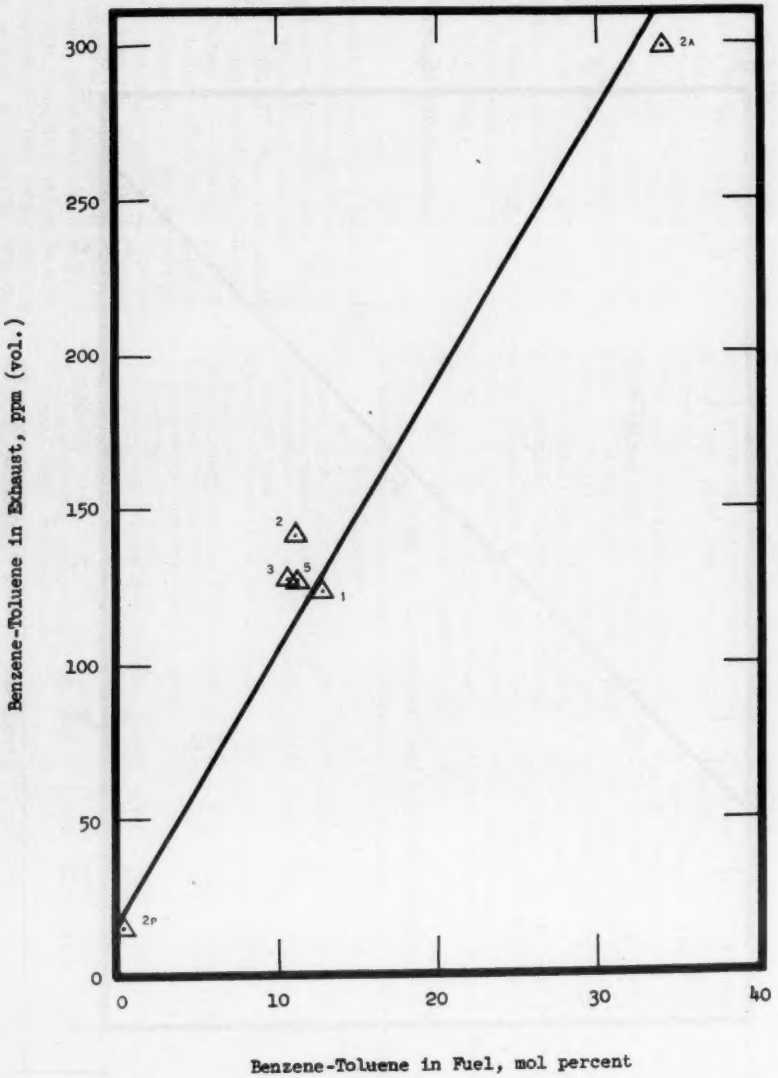

Fig. 3.

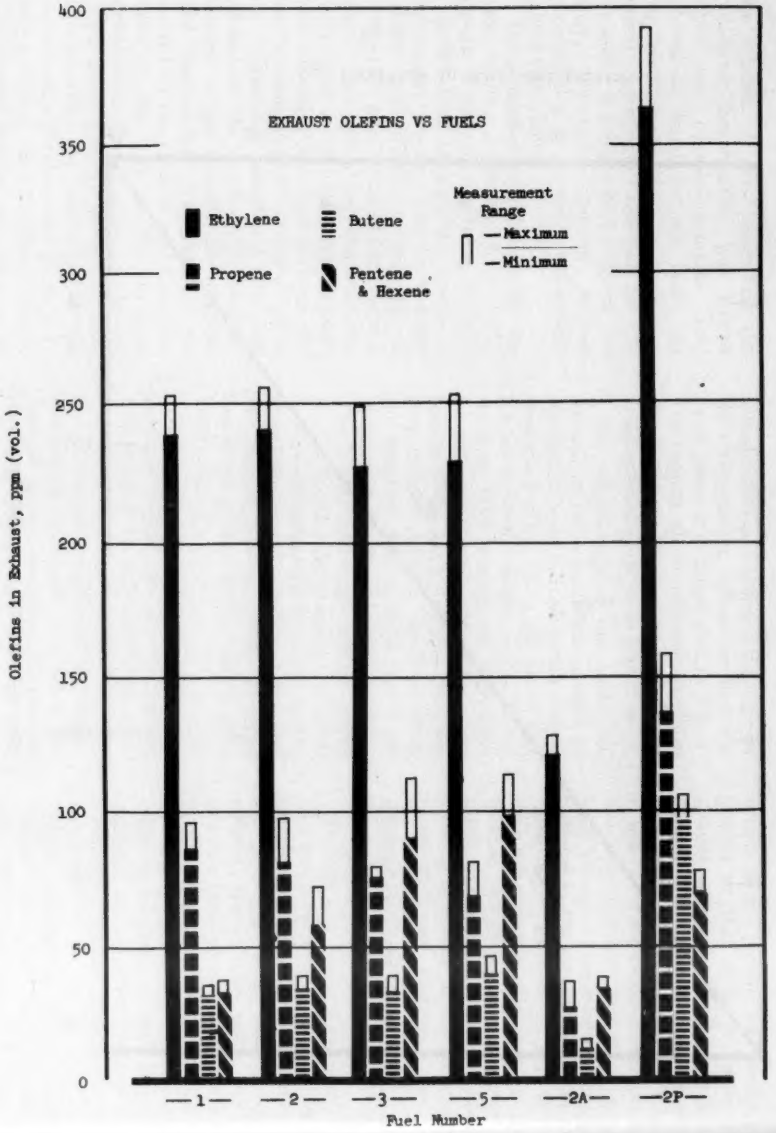

Fig. 4.

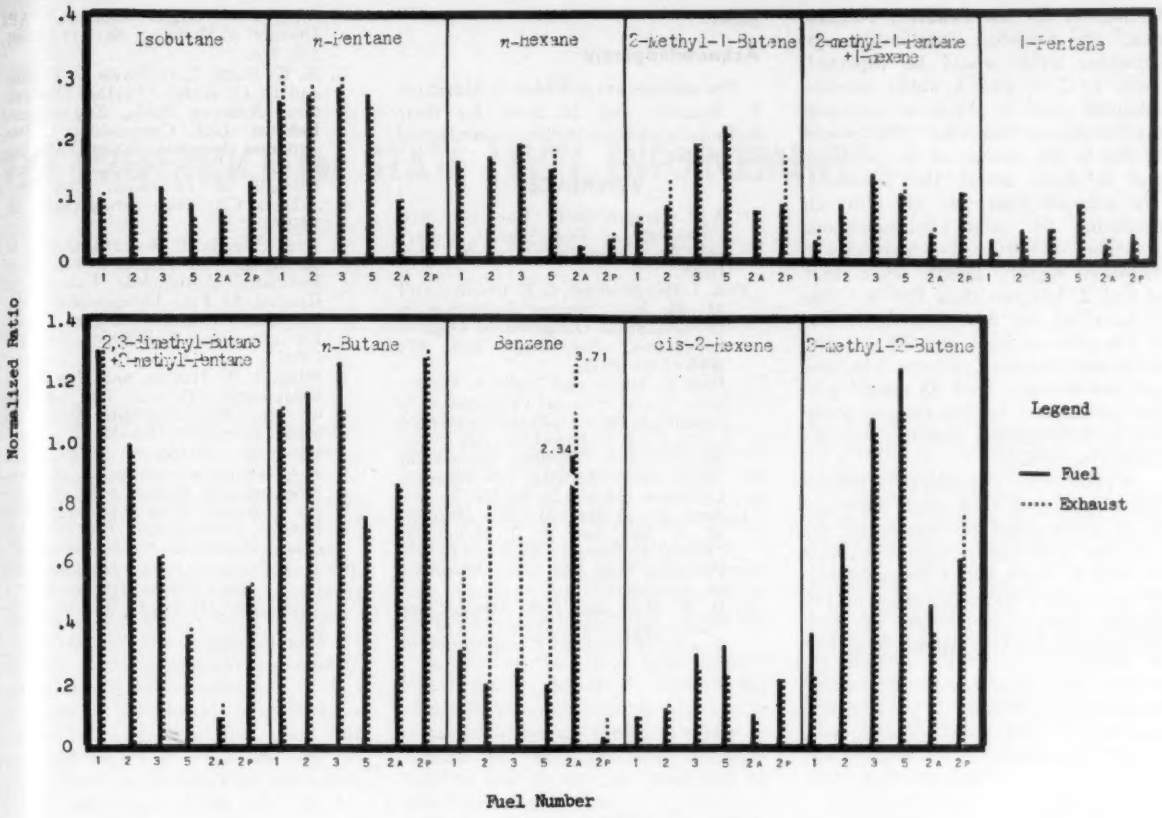

Fig. 5. Normalized hydrocarbon in fuel vs exhaust.

Again treating the C_4-C_6 paraffinic compounds as unburned fuel a linear increase for these substances was noted in all exhaust gases as the paraffin concentration was increased (Fig. 2).

The concentration of acetylene in the exhaust did not seem to be materially influenced by the increase in paraffin compounds. Methyl acetylene, however, did appear to increase.

The diolefin concentrations tended to show a slight increase but this is indeterminant.

Effect of Increased Aromatic Content in Fuel

Fuel 2A, which has an aromatic concentration of approximately 70 mol percent and an olefinic fraction near that of fuel 2, produced an exhaust which was unique when compared to those of the other fuels. Ethylene was produced in much lower quantities than in the other fuels. This was also true of the C_3-C_4 olefins as well as olefins in the C_5-C_6 molecular weight range. When considering the C_5-C_6 olefins, it would be expected that these would conform closely with those found in fuel 2. In the case of the exhaust from fuel 2A it was found that its C_5-C_6 olefins were at the same level as fuel 1 (Fig. 4). This may indicate that in the combustion of the high aromatic fuel, the fuel was more completely consumed. This decrease was also noted for acetylene which had remained at relatively the same level of concentration in the exhaust gases from the other five fuels.

Conclusion

Among the six fuels studied it was found that the hydrocarbon composition of the integrated exhaust gases was in each case related to the composition of its parent fuel. The make-up of the fuel determines the exhaust composition not only in regard to relative concentrations of the unburned fuel components, but also the types and quantities of cracked products produced.

The cracked products were found to consist almost entirely of C_2 to C_4 olefins and C_2-C_3 acetylenes. While methane and ethane were not recovered, these must also be included as major compounds resulting from thermal cracking in the engine. The remaining paraffinic and olefinic hydrocarbons recovered in the exhaust gases were shown to follow closely the relative concentrations found in the parent fuel. The aromatic compounds, benzene and toluene, did not follow this trend but are found in greater relative concentrations in the exhaust. The reason for this apparent increase is not known.

In evaluating the data obtained from this series of tests, the olefinic compounds are of major interest, as they have been pointed out to be one of the principal reactants in Los Angeles smog. In the more typical marketed fuels (1, 2, 3, and 5) an increase in fuel olefins was reflected by an increase of unburned fuel olefins in the exhaust gases, while the nature and concentration of the cracked products remained essentially the same. The combustion of the high alkylate fuel (2P) resulted in the formation of the highest concentrations of cracked olefinic products, but again, the pentenes and hexenes remained at a relative level consistent with the concentrations obtained from fuel analysis. The high aromatic fuel (2A) gave the lowest emissions of cracked products as well as unburned fuel olefins. When compared to fuels having a similar olefin content it was noted that in fuel 2A the relative concentrations of cracked products as well as unburned fuel olefins were approximately 50% lower in the exhausts.

The smog-forming potential of the exhausts produced from these fuels has not yet been determined. However, knowing the relative olefin concentrations in the exhausts and using the

findings of the Air Pollution Foundation,[7] the following comparative eye irritation levels would be expected. Fuels 1, 2, 3, and 5 would produce exhausts which would show increasing eye irritation in that order. This would be due to the increase of the pentenes and to some extent the 2-butenes. The exhaust from fuel 2P, although producing the larger concentrations of olefins, would yield a level of eye irritation slightly greater than that of fuel 2, but less than fuel 3. This is based on the fact that the olefins in the exhaust from fuel 2P are predominantly ethylene, propene, 1-butene, and isobutylene. Fuel 2A should give the lowest level as it is comparatively low in both cracked products and unburned fuel olefins.

At present the end effects of the exhausts produced from these fuels are being investigated by irradiating the exhausts in an environmental chamber in order to give a better understanding of the effects of fuel composition on Los Angeles smog. The results of these experiments will be published in a later paper.

Acknowledgment

The authors are indebted to Margaret F. Brunelle and D. Saeli for their technical assistance in the preparation of this paper.

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54th ANNUAL MEETING

JUNE 11–15, 1961

HOTEL COMMODORE

NEW YORK, NEW YORK

The PREFERENCE *for* STATE *LEVEL* ENFORCEMENT*

R. E. HATCHARD, Chief, Air Pollution Control, Oregon State Sanitary Authority, a Division of the State Board of Health

It is generally accepted that responsibility for the administration of a program for the prevention and abatement of air pollution should be at that level of government capable of dealing with the problem in its entirety.[1] This principle suggests the desirability of air pollution control at the local or regional level. However, due consideration should be given to the role of the state in activities intended to assist in accomplishing this objective.

There is considerable argument or confusion concerning the state air pollution programs which are now organized and functioning with due regard to the principle. There are two requirements included within the broad statement; first that the land area should include the community air pollution problem and secondly that the program resources must provide the capabilities to study, develop, and administer the problem within the land area. I should emphasize that capability includes the staff, budget, laboratory resources, ordinance, and regulations required to produce adequate prevention and control of air pollution.

When air pollution prevention or control becomes a recognized need, there are few cities or regions that are prepared to embark upon the program development with no assistance from the state. It is doubtful if a community of less than 100,000 population[2] could secure enough local resources to carry on an adequate program without continuing assistance from the state. In this regard there are several situations where enforcement from the state level may be the preferred course of action.

Situations Where State Enforcement May Be Preferable

The first case where a state level program organization, administration, and enforcement is desirable includes the few states that are small in geographical area, highly urbanized, and the entire state is within one community air pollution circumstance—at least under certain meteorological conditions. The role of the state in these cases may really be the organization of a local program at the state level. I emphasize that the local area includes the boundaries of the entire state by coincident. This condition does not involve many of the 50 states.

Another example where state primary jurisdiction is preferred involves the effects of air contaminants that create a hazard to human health in a city or community where the staff and supporting sources are not adequate to investigate the matter.

There are several other cases where the role of the state should be directed towards the local air pollution problem that should be considered as unique. One case is the situation where a group of citizens have petitioned the local public officials for investigation and abatement of an alleged public nuisance involving a source or sources of air pollution and no appropriate action is taken. I know some of you think—well, there is the ballot box which the citizens may use for expressing their dissatisfaction and there is also the mandamus action available to arouse citizens to force action by the public officials. Yes, this is very true but perhaps you will agree that the air pollution conditions must be severe or acute in order to stimulate the citizens to this degree of action. Therefore, I submit that it is not in the public interest to allow such a degradation of governmental responsibility and performance. A far better approach, I think is for the local citizens to petition the state air pollution agency to obtain appropriate action. Of course, the subsequent field investigations by the state group should stimulate and promote the local program to assume jurisdiction in order that the state group may shift to an assisting role.

Another case where state action is preferable includes the large metropolitan urban centers that are geographically located in parts of two states. It is estimated that 1/4 of the people in the United States live in approximately 23 standard metropolitan statistical areas—that cross state boundaries.[3]

It should be apparent that the needs of urban complexes for assistance to assure reasonable community air quality require states to provide program services to meet this need. In this case the preference for state activity including enforcement is over federal jurisdiction. However, if states do not assume the initiative and respond adequately it should be recognized that this deficiency may be the basis for another call for assistance from the federal government.

In recent years the state activities in resource, study, planning, and development have increased greatly. It is now recognized that air, like water, is a limited resource[4] which is most pronounced when a temperature inversion and low wind speed restrict the capacity of the atmosphere to satisfactorily dilute the air. The state has an obligation to develop leadership toward the development of co-ordinated local, regional, and interstate actions to control and prevent air pollution.

State Statutes

Fortunately there has been a considerable increase in states' activity in the organization of air pollution programs authorized by statute. The first of these laws[5] was adopted in Oregon in 1951 and provided for the organization of an Air Pollution Authority as a division in the State Board of Health. Similar comprehensive legislation was adopted in 1954 by the states of Massachusetts and New Jersey; Delaware, Florida, New York, and Hawaii in 1957; and Idaho and Pennsylvania in 1959.

The second type of state statute provides enabling legislation for counties or groups of counties and districts to organize programs. The state of California created such a statute in 1947 followed by Kentucky in 1952 and Washington, Nevada, and Florida in 1957. A variation of the enabling legislation provides for limited control by cities or counties of a certain classi-

* Presented at the 53rd Annual Meeting of APCA, Netherland-Hilton Hotel, May 22–26, 1960, Cincinnati, Ohio.

fication or population size; and was adopted by the states of Missouri, North Carolina, South Carolina in 1952, Nebraska in 1954, Rhode Island in 1956, Wisconsin in 1957, and Pennsylvania in 1959.

The third type of state statute provides technical assistance and research at the state level and was adopted in California in 1955, Ohio in 1957, and Tennessee in 1959.

Essential Policies and Relationships

There are several essential policies and relationships that must be understood and followed if the role of the state is to be successful in the prevention and control of community air pollution and are stated as follows:

1 Recognition that local government should assume primary administrative and enforcement jurisdiction where ordinances and supporting services are adequate. The proper state role then is to assist the local jurisdiction with program operation.

2 That the local program staff assume primary responsibilities for co-ordination with other city functions concerned such as planning and zoning, fire, building permits, and other city engineer activities.

3 That the primary role of the state program should be to adopt appropriate regulations including air quality and source discharge standards, conduct specialized air sampling surveys when equipment or staff is not available locally, prepare reports of investigations or surveys with recommendations, and related duties.

4 Recognition that the responsibilities of local, regional, state, and federal community air pollution activities must be flexible to the end that a maximum degree of local autonomy is achieved.

5 That the number and type of enforcement actions are closely related to the public demand for reasonable community air sanitation conditions.

Summary

The conditions where a preference for state enforcement action exists are summarized as follows:

1 Where the community air pollution problem includes the land area within the boundaries of a single state.

2 When the effects of air contaminants are based upon alleged human health injury and the local resources are not adequate for appropriate investigations.

3 When the local public officials fail to take appropriate action in response to citizen petitions or complaints demanding investigations and abatement.

4 Where the community air pollution problem extends beyond the borders of a single state.

5 For co-ordinated actions with the natural resource agencies' studies and recommendations at the state level.

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Air Pollution Control Association Membership Blank

1. Name (or company name).....
2. Mailing address.....
3. Individual members: Company, organization, or agency with whom you are affiliated.....
   Company or Sustaining members: Industry affiliation or type of business (steel, petroleum, equipment, etc.).....
   .....
4. Class of Membership (please check)

		Dues
Individual	☐	$ 15.00
Company Member (Local)	☐	$ 50.00
Company Member (National)	☐	$100.00
Government Agency Member	☐	$ 50.00 (Minimum)
Organization Member	☐	$100.00
Sustaining Member	☐	$250.00 (Minimum)

5. Check enclosed herewith ☐
   Send bill for dues ☐
6. Company or sustaining member's delegated voting representative is:
   Name.....
   Title.....
   Address.....
7. Signed.....
   Title.....
   Date.....

Here is an opportunity to help your Association get its membership campaign off the ground. Use this application blank for new individual, company or sustaining members. If each APCA member brings in just one new member, we'll be well over the 4000 mark.

NEWS FROM THE CONTROL DISTRICTS

Bay Area

Dr. John T. Middleton, chairman of the State Motor Vehicle Pollution Control Board, emphasized to the Advisory Council of the Bay Area Air Pollution Control District that the co-operation of counties and air pollution control districts is vital to fulfill the State's anti-auto smog program.

"Seventy companies have requested application forms from the State Board, as required to have their anti-auto smog devices tested, and we should certify two or more devices this year," Dr. Middleton told the Council. All new cars in the State would then be equipped with devices by 1963, and used car emissions would be controlled by 1964. Individual counties, however, may vote themselves out of the law for used cars.

State Assemblyman W. Byron Rumford introduced a bill (AB 1228) in the State Assembly to amend the six-county Bay Area Air Pollution Control District's Law to provide a one cent increase in the District's permissible tax rate.

In speaking about the bill, Assemblyman Rumford said, "The Bay Area Air Pollution Control District is moving along in its program to clean the air. The work that has been done by the District and their air pollution control program for the future will attain this goal.

"The need for added funds has been determined by the Budget and Finance Committee and the full Board of Directors of the Bay Area APCD in the interest of the health and welfare of the people of the Bay Area," he added.

Steel Mills Experiment

Four Bay Area open hearth steel mills are currently involved in a $250,000 gamble, which, if successful, will reduce their smog-producing smoke stack emissions by more than 99%, according to Benjamin Linsky, Control Officer of the Bay Area Air Pollution Control District, who also stated mills will be in full compliance with District's regulations by 1963.

Each plant has several smoke stacks that emit obvious plumes of microscopic dust, amounting to more than 75 pounds per hour from each stack.

Leading the way in this super anti-smog experiment, which is bent on full compliance with the Bay Area APCD's tight Regulation 2 by 1963, is Bethlehem Steel's South San Francisco plant.

The costly gamble involves a new engineering development called a "non-shaking baghouse," discovered accidentally in a cement plant, and never before used on a steel mill's open hearth furnace. The unique "baghouse" operation consists of a series of high temperature cloth filter collectors. Small scale units which cost from $15,000 to $40,000 each have been tested at each plant. Bethlehem is currently installing a fullscale collector of this type, at a cost of about $250,000 to clean just one of its open hearth stacks. Final testing is expected to be completed late this year.

City of Columbus

Four summons were issued during the month to: one hotel, two commercial buildings, and one government building. All agreed to take whatever corrective measures were necessary to eliminate the excessive smoke. No punitive action was necessary.

Personnel of the division were asked to attend a meeting with the firemen of several government buildings to give advice on proper firing methods to help eliminate smoke.

Several meetings were held to discuss the passing of an ordinance to allow debris burning. The immensity of the amount of debris to be handled this year alone, from improvement projects in the city, demands considerable consideration in seeking a solution to the problem before this division can agree to any ordinance permitting "open fire" burning.

At a meeting of the Advisory Board, Division of Smoke Regulation, City of Columbus, January 12, 1961, the following resolution was unanimously adopted.

> "The Advisory Board hereby wishes to command the entire Smoke Regulation Department for their work during the past year, and want to assure the department of full co-operation of the Board for the coming year."

Los Angeles

Unless natural gas is substituted for fuel oil in power plants, air pollution from the generation of electricity will increase almost fourfold in 20 years, Air Pollution Control Officer Smith Griswold told the State Public Utilities Commission.

Gas creates only one-seventh as much pollution as oil, Mr. Griswold said, testifying in favor of an application by the California Gas Transmission Company and Southern California Edison Company to import gas from Mexico and Texas.

At present, substituting gas for oil at all power plants reduces pollution from 760 to 110 tons per day. Anticipated expansion of electrical generating facilities in Los Angeles County will result in daily pollution totals of

(Continued on p. 190)

DISCUSSION TO BE HELD AT NPA SPRING MEETING REGARDING AP PROBLEMS

A notable group of petroleum and nonpetroleum industry spokesmen from all sections of the United States will discuss air pollution problems and possible solutions to them at the National Petroleum Association's Spring Meeting April 19–21 at the Hotel Sheraton-Cleveland in Cleveland, Ohio. The symposium discussion, developed by W. L. Faith and H. F. Elkin, will feature three sessions with a morning session devoted to technical matters, a luncheon session to trends in air pollution legislation, and an afternoon session featuring a panel discussion of "Air Pollution Control in Major Refining Areas."

To be presented in the most comprehensive symposium in the past several years, jointly participated in by petroleum and nonpetroleum industry spokesmen, will be introductory remarks by Chairman W. L. Faith of the Air Pollution Foundation, San Marino, California, and a paper dealing with the hydrocarbon problem. The sulfur dioxide problem will be discussed by Louis C. McCabe, Resources Research, Inc., Washington, D. C., while Richard F. O'Mara, Los Angeles, California, will discuss particulate matter. At the luncheon session E. B. McConnell, Standard Oil Company of Ohio, will introduce L. C. Burroughs, Executive Secretary, API Smoke and Fumes Committee, who will discuss "Trends in Air Pollution Legislation." The afternoon panel discussion, covering "Air Pollution Control in Major Refining Areas," will be moderated by H. F. Elkin of Sun Oil Company and will cover reports from Los Angeles by R. T. Mapston, Richfield Oil Corporation; from the San Francisco Bay Area by H. G. Vesper, Standard Oil Company of California, Western Operations, Inc.; from the New York-New Jersey area by E. S. Swanson, Humble Oil and Refining Company; from the Delaware Valley area by R. D. Bent, Atlantic Refining Company; from the Chicago area by P. M. Gammelgard, Pure Oil Company; from the Gulf Coast by N. E. Pennels, Sinclair Refining Company, Houston, Texas.

East Central Section Annual Technical Meeting—
September 21, 22, 1961,
Louisville, Kentucky

Technical papers on air pollution control and related subjects are solicited for presentation.

For further information write to
Ralph W. Bourne, Room 2, City Hall, Louisville 2, Kentucky

CONTROL DISTRICTS

(Continued from p. 189)

1610 tons in 1970 and 2710 tons in 1980, if oil continues to be used, Griswold pointed out.

Although the burning of fuel oil is now forbidden during six months of the year under Rule 62, there is not sufficient gas available to permit its use during the winter when demand for domestic heating is highest. The proposed new pipeline will assure the power plants of the gas needed for year-round operation.

Burning fuel oil creates a large amount of oxides of nitrogen, an air pollutant, Mr. Griswold said. Oxides of nitrogen levels reached a new peak in Los Angeles during January and a group of 40 air pollution and public health authorities last week recommended that immediate steps be taken to reduce emission of this contaminant from all sources. Replacing fuel oil by natural gas reduces oxides of nitrogen by 120 tons a day, and reduces another toxic contaminant, sulfur oxides, by about 500 tons a day.

For adapting and developing a simple field test for olefins in gasoline, Maurice E. Fykes, Jr., senior air pollution engineering inspector, has been awarded $100 by the Los Angeles County Suggestion Awards Board.

Use of this method replaces thousands of expensive laboratory analyses and will result in a saving estimated at more than $5000 in the current year. At the end of that time, Mr. Fykes will receive a further award based upon the exact number saved.

New York City

Sootfall in New York City declined in 1960 for the second straight year, it was announced by Arthur J. Benline, Commissioner of the New York City Department of Air Pollution Control. This marks the first two-year drop in sootfall since 1951–52, Commissioner Benline said.

Again in 1960, other pollutants, with the exception of those from automotive vehicles, declined or rose only slightly. Oxidants and carbon monoxide, major pollutants from automotive vehicles, increased in amount, while nitrogen dioxide remained the same during 1960, as in 1959.

Commenting on the increase in automotive pollution, Commissioner Benline said: "Our statistics indicate that something must be done about pollution from automotive vehicles. Fortunately, one aspect of this problem—the approximately one-third of the total pollution from an automotive vehicle which blows past the piston rings and crankcase—can be controlled by a simple and inexpensive device. Installation of this crankcase blowby device will also result in better, more efficient operation of the vehicle and in fuel savings. Legislation now before the State Assembly and Senate would make this blowby device mandatory on all new cars sold in New York State after September 1, 1961. It is vital that this bill be passed, so that a start can be made against this increasing problem."

The average tons of sootfall per square mile per month which fell on the City in 1960 was 68.3, compared to 70.6 average tons per square mile per month in 1959.

A new record for violation notices served by the New York City Depart-

(Continued on p. 191)

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Personalia

Joseph W. Lenehan has been elevated to the position of Vice President and Director of Engineering of the Air Pollution Control Division of the John Wood Company. Mr. Lenehan's responsibility will encompass engineering, and development for the Division which has its headquarters in Florham Park, New Jersey. The appointment was announced by Mr. Guy George Gabrielson, President of John Wood Company.

J. W. Lenehan

The new appointment reflects the increasing activity of the Air Pollution Control Division. Mr. Lenehan, a graduate mechanical engineer, has been active in the field of air pollution control for over 15 years. He has designed dust collection equipment, electrostatic precipitators and scrubbers, and large-scale individual installations costing in excess of $1,000,000. In his new post, he will be responsible for the engineering of installations and the expansion of John Wood's now extensive line of equipment.

* * *

Richard G. Genton has joined Wheelabrator Corporation, Dust and Fume Control Division, Mishawaka, Indiana, and has been assigned to a three-state territory including California, Nevada, and Arizona where he will serve as Regional Dust and Fume Engineer, operating from Wheelabrator's Los Angeles and San Francisco offices.

Mr. Genton's background in dust and fume control covers a wide range of industries including chemicals, rubber, mining, ore beneficiation, iron and steel. Over the past six years, he has engineered and designed complete systems, developed integrated process dust control equipment, served as project engineer for inplant environmental control and filtration of process emissions to prevent air pollution, and has acted as a supervising sales engineer for field forces.

* * *

Charles H. Marks recently joined The Foxboro Company, Foxboro, Massachusetts, as a Senior Systems Engineer in their Computer Tech-

(Continued on p. 192)

CONTROL DISTRICTS

(Continued from p. 190)

ment of Air Pollution Control was established in 1960. The year also showed an almost 10% decline in citizen complaints, while fines levied in Municipal Term Court were the second highest in the history of the Department and summonses issued were the third highest since the Department was established in November 1952.

Last year, Commissioner Benline reported, the Department's Bureau of Inspection responded to 15,615 complaints and served 5077 violation notices. Fines totaling $16,400 were levied in Municipal Term Court as a result of the issuance of 559 summonses. The Bureau of Inspection held 94 office hearings with offenders and ordered 561 smoke alarms to be installed in buildings throughout the City.

Allegheny County

Another battle in the steel industry's continuing war against air pollution in Allegheny County has been won by United States Steel's Duquesne Works, it was announced jointly by Dr. H. R. Domke, director of the County Department of Health, and S. M. Jenks, executive vice president, engineering and research, of United States Steel.

A smoke-filtering system, developed by a U. S. Steel team of research, engineering, and operating personnel, is under construction at the Duquesne Works' electric arc steelmaking shop, Dr. Domke and Mr. Jenks stated.

"United States Steel's 'break-through' in the problem of controlling smoke emitted by electric furnaces is another result of the efforts made by the steel industry in this area to reduce air pollution," Dr. Domke said. "Corrective devices of the various steel companies, while not adding to steel production or efficiency have nevertheless been installed at substantial cost to achieve a record in which the city, county and steel industry can take pride."

In making the joint announcement of the smoke control plans for Duquesne Works, Mr. Jenks stated:

"The concentrated studies undertaken by the steel industry covering air pollution are bearing fruit. As a member of the Air Pollution Control Advisory Committee, I am proud that these studies have resulted in the development Dr. Domke and I are announcing today. The Duquesne Works' installation is one phase of a program that assures Allegheny County's continued leadership in air pollution control."

Operating much like a giant vacuum cleaner, the Duquesne Works system will collect almost all of the smoke emitted by the plant's five electric furnaces, then filter out the solid particles by pushing the smoke through a series of 30-foot-long fiber glass fabric bags.

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detects and measures hydrocarbon traces in gases and atmospheres

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- measuring hydrocarbon contamination in LOX, other missile and aviation gases
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- checking leaks — packaging, gas transmission lines, storage areas, refrigeration equipment
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CALENDAR

April 18–20	International Symposium on Chemical Reactions in the Lower and Upper Atmosphere, San Francisco, California.
April 19–21	National Petroleum Association Spring Meeting, Cleveland, Ohio.
June 11–15	**54th Annual Meeting of APCA, Hotel Commodore, New York, New York.**
June 19–23	Air Cleaning Institute, Harvard University, School of Public Health, Boston, Massachusetts.
September 21–22	East Central Section Annual Technical Meeting, Louisville, Kentucky.

MOTOR VEHICLE CONTROL BOARD SET TO FIGHT CALIFORNIA AUTO EMISSIONS

Hottest air pollution item on the West Coast scene is California's long-anticipated plan to control automobile emissions.

The program was put into gear by 1960 State Legislature action setting up the Motor Vehicle Control Board and establishing a timetable for the application of approved control devices to autos. The Board has since hired Donald A. Jensen as Executive Officer and has commenced the technical staffing of the organization. A contract has been signed with the Los Angeles County APCD to test automotive control devices.

Dr. John T. Middleton, Chairman of the Control Board, has stated that he expects at least two such devices to be certified satisfactory during 1961. Approval of two or more devices before the end of the year will set in motion the State's timetable. All new cars sold in California after December 31, 1962, would then have to be equipped with approved control devices. Used cars would be controlled in succeeding years.

Device Must Be Tested

To obtain certification it will have to be shown by test that the particular device will reduce specific contaminants below State Department of Public Health limits and in addition to meet whatever other criteria are deemed necessary by the Control Board. The Department of Public Health has established limits only for carbon monoxide and hydrocarbons. In addition, the Control Board is expected to set performance standards for such items as durability, ease of testing, and odors. The stringency of these criteria will undoubtedly have a profound effect on the eventual price of control devices.

If standards are set for nitrogen oxide emissions, the picture would be complicated somewhat. Most of the proposed auto exhaust controls are combustion devices designed to incinerate unburned exhaust products. These might be expected to increase rather than decrease nitrogen oxides.

Standards Adopted

In December the Department of Public Health also adopted standards for automobile crankcase emissions. These so-called "Blowby" losses are judged significant although tail pipe emissions are still considered the major source of auto pollution.

In contrast to tail pipe exhaust gases, crankcase emissions can be readily and inexpensively controlled. There are several manufactured items on the market which can be used. Gases from the crankcase breather cap are merely ducted to the air cleaner, intake manifold, or to the exhaust control device, if one exists. The installation of blowby controls has not yet been made mandatory but these devices are being offered for sale in all 1961 autos sold in California.

PERSONALIA

(Continued from p. 190)

nology Group. Formerly the Manager of Engineering of the National Coal Association, Mr. Marks is now responsible for the application of complete control and supervisory systems to the power industry. These control systems consist of Foxboro instrumentation and controls with RCA large-scale digital computers.

* * *

Dr. Natale Colosi, a member of the Interstate Sanitation Commission of New York for 13 years was recently elected vice-chairman of the commission. During his membership on the commission, Dr. Colosi has also served as acting treasurer and as chairman of the commission's by-laws committee.

A professor of bacteriology and public health at Wagner College and at the New York Polyclinic Medical School and Hospital, Dr. Colosi is also the executive director of Italian Hospital, Manhattan.

* * *

Dr. Christopher E. Barthel, Jr., has been appointed Program Director for Foreign Science Activities in the National Science Foundation's Office of Special International Programs.

Before joining NSF, Dr. Barthel had been with the Armour Research Foundation of Illinois Institute of Technology since 1947, where he served most recently as Assistant Director. In 1953 he directed the development of the Union of Burma's scientific and engineering research under a contract between that nation and Armour Research Foundation. Under his direction, necessary legislation for the support of scientific and engineering research activities was prepared and organizations to administer this work were established. Other administrative positions held by Dr. Barthel at Armour included Assistant-Director for Personnel, and Chairman of Physics Research.

Letters to the Editor

(Continued from p. 150)

am enclosing for your further information as requested, copies of the Cleaner Air Campaign Newsletter, a report on the Durban Cleaner Air Campaign, and a copy of the Smoke Control By-Laws for the City of Durban.

You will note that the third amendment of the Smoke Control By-Laws, dated November 10, 1960, relates to the establishment of a smokeless zone over the entire Central Area of the City. There are over 800 fuel-burning appliances in this Central City Area and the Legislation calls on all of them to be smokeless by February 10, 1961, or else apply to this Department for the necessary temporary exemption. These exemptions are only granted providing owners or occupiers investigate the use of smokeless fuels and are generally granted for one year where modifications or additions to the existing installations are required.

In Replacement Cases

In the case of installations which have to be replaced entirely to conform with the requirements of the Legislation, a period of two years is given and the Council operates a five-year Loan Scheme to ensure that no one suffers financial hardship through the implementation of this Legislation.

As you will see from the enclosed papers the Department's policy is one of all out co-operation with the owners and operators of all fuel-burning appliances etc. in the City to ensure speedy compliance with the By-Laws without incurring excessive expenditure or hardship. This policy has proved very successful and other Municipalities who have followed our progress with interest are now introducing similar control programs.

Yours faithfully,
A. KINMONT
City Engineer
City of Durban
South Africa

UOP to Test Product

Universal Oil Products has filed a formal application for California state testing of Purzaust, its catalytic automotive antismog device. The application was submitted through UOP's marketing and manufacturing subsidiary, Universal Oxidation Processes. It is the first application which carries test data to be received by the California State Motor Vehicle Pollution Control Board, UOP says. The data were compiled by UOP from two years of R&D tests and road tests.

Welcome New Members

(Continued from p. 174)

Jones, Leslie J.
South Pasadena, Calif.

Jordan, Charles E.
East Chicago, Ind.

Kafferlin, William H.
Linden, N. J.

Kaufman, Philip
Lynwood, Calif.

King, Charles B.
Corning, N. Y.

Knox, Charles E.
New York, N. Y.

Lodge, James P., Jr.
Cincinnati, Ohio

Long, Harold W., Jr.
Bartow, Fla.

McNab, Melvin E.
North Tonawanda, N. Y.

Montgomery, W. T. S.
Jacksonville, Fla.

Munn, George H.
Lansdowne, Pa.

Melby, Anton O.
Los Angeles, Calif.

Negus, J. Henry
Summit, N. J.

Otto, Robert L.
Mount Airy, Cincinnati, Ohio

Parton, Julian
Easton, Pa.

Pastell, Daniel L.
Los Angeles, Calif.

Pfennig, H. W.
Houston, Tex.

Punte, Charles L.
Army Chemical Center, Md.

Roper, J. W.
Cleveland, Ohio

Ross, John H.
Toronto, Ontario, Canada

Sanderson, H. P.
Ottawa, Ontario, Canada

Scholes, J. Fred
The Dalles, Ore.

Scripps, Thomas O.
Los Angeles, Calif.

Sealy, Harry T.
Cleveland, Ohio

Southwick, Eva B.
Falmouth Foreside, Maine

Smith, Denholm
Hinton, Alberta, Canada

Smith, Seymour
New York, N. Y.

Steiner, William R.
Indiana, Pa.

Stowe, Vernon M.
East St. Louis, Ill.

Stubenbort, J. W., Jr.
Library, Pa.

Theys, Leon
Brussels, Belgium

Harold H. Todd, Jr.
Brookfield Center, Conn.

Tynan, Desmond P.
New York, N. Y.

Verleger, Philip K.
Los Angeles, Calif.

Verrochi, William A.
Boston, Mass.

Walker, Hugh Leslie
Toronto, Ontario, Canada

Walmsley, Alexander W.
Niagara Falls, N. Y.

Weitzel, Walter G.
Providence, R. I.

Wood, Bruce
Bethlehem, Pa.

THREE BY-LAW AMENDMENTS SUGGESTED BY DIRECTORS AND LEGAL COMMITTEE

In accordance with Article XIII of the By-Laws, the following two amendments are quoted for the information of the membership. These by-law amendments were initiated by the Board of Directors at their October 25, 1960 Meeting as required in Section 1 of Article XIII.

The By-Law Amendment concerning powers of the Executive Committee has been needed for many years to facilitate the conduct of Board Meetings, and to allow the Executive Committee authority to take interim action in between Board Meetings. It was approved unanimously by the Board.

The By-Law amendment concerning dissolution of funds is required by the Internal Revenue Service for tax-exempt nonprofit organizations and must be passed if APCA is to maintain its status as a tax-exempt organization.

These amendments will be discussed at the Business Meeting of the Association on June 12 in New York, as required in section 2 of Article XIII, and then voted upon for adoption after the Annual Meeting.

Proposed By-Law Amendment for **Power of Executive Committee.** Article IX—**Officers,** Section 1, Paragraph 4.

The Executive Committee shall consist of the President, the immediate Past President, and the four (4) Vice Presidents.

The Committee shall meet at the call of the President. The Executive Secretary and Treasurer may take part in the deliberations of the Executive Committee without vote. The Executive Committee shall keep minutes of its meetings which shall be forwarded to each member of the Board.

The Executive Committee shall have and may exercise all of the powers of the Board of Directors when the Board is not in session, with the exception of such powers as may appear in the By-Laws or as the Board may specifically reserve to itself, or as may be specifically assigned to any other committee or to any officer of the Association. The Executive Committee shall make and adopt such rules and regulations as it may deem prudent for its management.

Proposed By-Law Amendment for **Dissolution and Disposal of Funds as Required by Exempt Organizations Branch of the Internal Revenue Department.** Article VI, Section 2. **Association Assets.**

In the event of dissolution of the association the remaining assets after discharge of all liabilities and obligations shall be donated to another nonprofit association or organization, doing similar or like work in the field.

A third By-Law amendment was suggested by the Legal Committee and initiated by the Board of Directors at Cincinnati on May 22, 1960. It has to do with the clarification of succession of Presidency. It is a revision of Section 2 of Article IX.

Section 2. Should the President die or for any reason submit his resignation to the Board, sending such resignation to the Executive Secretary stating the effective date of such resignation, the First Vice President shall immediately succeed to the presidency until the next election. In the event that because of death or resignation of the president, the First Vice President shall succeed to the presidency until the next election, and the President so succeeded shall have been a full time representative of an air pollution control agency, the requirement of Section 1 of this article with respect to the holding of office by such a representative shall be deemed to have been fulfilled for that year. The President (replaced) shall continue to serve as a Board Member, however, until the next election. If the President or any member of the Board shall change his employment category, he shall notify the Executive Secretary within thirty (30) days after the effective date of such change. Such change in employment shall not disqualify the President from continuing to serve as President until the expiration of his term of office. Any member of the Board who changes his employment category may serve on the Board only until the next election. At the next election, he may be considered as a candidate by the Nominating Committee to complete his original term, in which case he shall be considered in his employment category at the time of his nomination for re-election.

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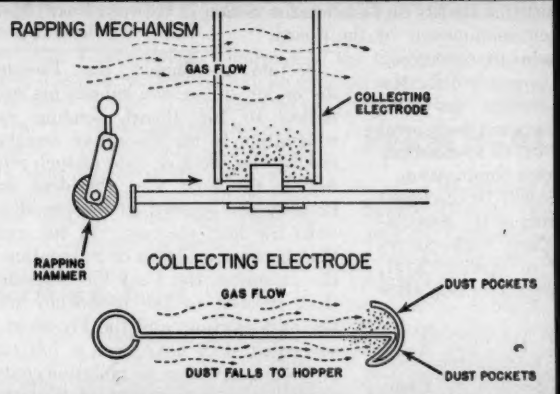
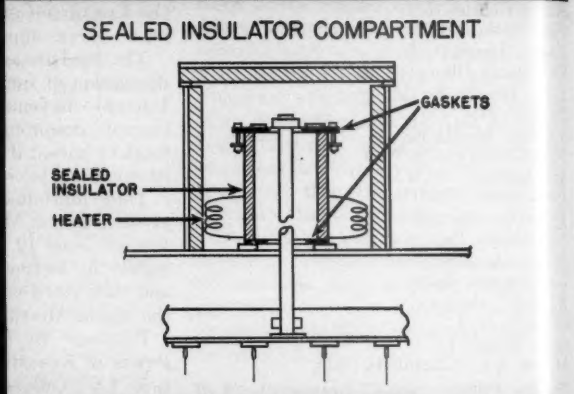
SOME PLAIN FACTS

ABOUT SUPERIOR PRECIPITATOR PERFORMANCE

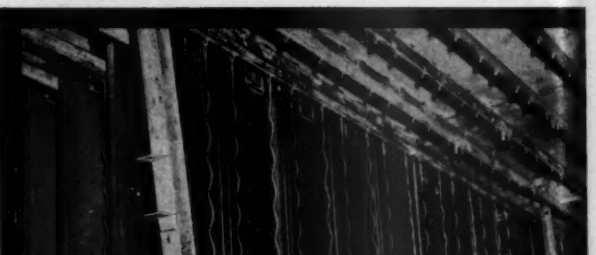
Buell Precipitators are designed and constructed for rugged service and superior performance. Frills and internal frim-fram of a doubtful value are eliminated in favor of strength and simplicity. The casing, outside supports, and internal parts are of rugged construction; and the four-point suspension of emitting electrodes ensures the greatest stability. Here are just a few of the outstanding features of Buell Precipitators.





Effective Continuous Cycle Rapping—Yes, it's mechanical. A simple, rugged system free of complicated gadgets; assures positive dust shearing action. Each row of electrodes is rapped separately—in the direction of the gas flow—on a continuous cycle. Dust is sheared off, drops in an agglomerated mass and pockets on electrodes minimize reentrainment.

Sealed Insulators Improves Operation—High voltage quartz support insulators are completely sealed; prevents gas and dust leaking into insulator compartment and outside air leaking into precipitator. There is no need for costly ventilating systems. Thermostatically controlled electric heaters insure start-up without danger of moisture condensation and insulator breakdown.



Uniform Distribution of Gas Flow—Field adjustment capability is vital. Buell's adjustable baffle permits final positioning after field measurement of actual flow distribution . . . because gas flow patterns are not entirely predictable. The Buell distribution system assures equal gas loading through the precipitator; eliminates ineffective "dead" areas around passages and prevents "sneak-by."

Buell Spiralectrodes cut maintenance to a minimum. Buell's record stands at less than 1% replacement in this key area. Self-tensioned spiralectrodes eliminate vibration and "off-center" swaying, often prevalent with weight-tensioned wires. They're structurally fixed and once installed stay in alignment. The spiralectrode provides greater emission than straight wires.

Buell precipitators are simple and effective. They're designed for continuous service. You'll be glad you turned to Buell when you experience superior performance and low maintenance. Detailed literature describing all features is available.

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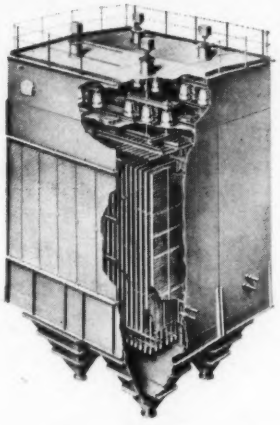
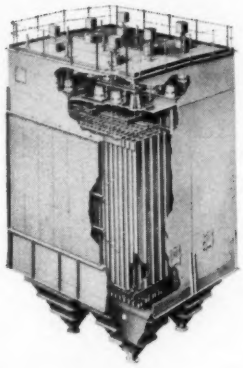
The Buell Engineering Co., Inc., Dept. 51-D, 123 William Street, New York 38, N. Y. Northern Blower Division, 6438 Barberton Avenue., Cleveland, Ohio. ■Electric Precipitators ■Cyclones ■Bag Collectors ■Combination Systems ■Fans ■Classifiers.

How to Evaluate Cottrell Precipitators

How Important Is Precipitator Size?

Traditional Design →





Modern Design ←

As shown in these two illustrations, Research-Cottrell's more compact modern design is appreciably smaller than the traditional design.

A common fallacy assumes a larger precipitator with lower gas velocity is preferable to a smaller precipitator with higher gas velocity.

This assumption overlooks important economies now obtained with:

(a) Efficient voltage application.

(b) Specific control of electrical sections.

(c) Electrode design improvements.

(d) Automatic Rapper Control.

(e) Accurate internal baffling.

(f) Proper control of gas flow, based on three-dimensional model studies.

Close familiarity with these techniques and improvements has made possible guarantees of 99 per cent collection on large, modern installations.

A. Applied Voltage

The relationship between voltage and size of the precipitator is approximately as shown in Figure 1.

Most efficient operation and minimum size are obtainable by insuring operation at maximum voltage under varying conditions of gas flow, particle size, resistivity, etc. Generally, the amount of arc-over in the precipitator will determine the practical operating voltage limit. By using the arc-over as the motivating control factor, through measurement and integration, maximum voltage can be insured at all times.

B. Sectional Voltage Control

Since gas conditions vary throughout any precipitator, higher efficiencies are obtainable if the precipitator is sectionalized with individual voltage control for each section.

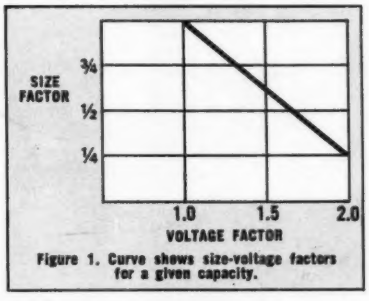


Figure 1. Curve shows size-voltage factors for a given capacity.

C. Electrode Design

Efficiency can be seriously affected by re-entrainment (that is the re-suspension of dust that has already been collected). Properly designed collecting electrodes, or plates, providing correct baffling to shield the collecting surface against the sweeping and scouring effects of the gas stream can reduce overall precipitator size 25–50 per cent.

D. Automatic Rapper Control

Rapping intensity must vary to meet the changing conditions of gas flow, particle size and resistivity. Otherwise, efficiency will decrease due to either too heavy a blow causing a re-entrainment, or too light a blow allowing dust build up on the electrodes necessitating operation at reduced voltages. Automatically controlled, fully adjustable rapping equipment insures optimum operation at all times.

E. Internal Baffling

Maximum efficiency can only be obtained by reducing the sneakage (part of gas stream which leaks or sneaks around the treatment zone) to an absolute minimum through the proper design and use of internal baffling proven by model studies and research on full size precipitators.

F. Gas Flow—Model Studies

Proper gas flow patterns across the face of the precipitator can result in a 25–50 per cent reduction in over-all size. The use of transparent plastic three-dimensional model studies as well as field research has resulted in refinements in design never before possible.

Only at Research-Cottrell can you be assured of these latest of design techniques and improvements providing the most economical selection of equipment and efficiency of operation. Research-Cottrell personnel, backed by nearly a half century of gas cleaning experience, stand ready at any time to provide information or service.

For details or more information relative to the data contained herein, or any other general inquiries, please contact your nearest Research-Cottrell representative or write directly to:

Research-Cottrell, Inc.
Office and Plant: Bound Brook, N. J.
Representatives in Principal Cities of U.S. and Canada. RC223

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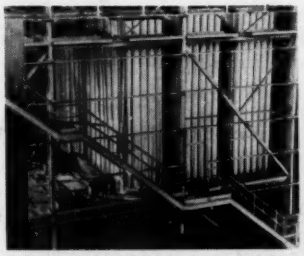
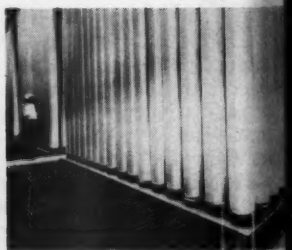
500°F FILTRATION

- ...filter bags made with STEVENS glass fabric with SLKN™ finish operate efficiently at temperatures above 500°
- ...eliminate the need for costly cooling equipment
- ...will not shrink or stretch
- ...have high collection efficiencies
- ...are unaffected by most corrosive fumes
- ...afford easy cake release due to the extra smooth water repellent SLKN™ surface
- ...STEVENS Fiber Glass Filter Fabric Clinic is available for research and development on a confidential basis
- ...names of fabricators of filter bags made with STEVENS SLKN™ glass fabric will be supplied upon request



Stevens' glass filter bags are gaining widespread acceptance as media to clean industrial plants' gas and smoke exhaust and thus reduce air pollution and smog.



This dust collection unit at the Ideal Cement Co. has 1280 glass fabric filter bags which catch about [illegible] tons of dust a day.

FINE FABRICS MADE IN AMERICA SINCE 1813

J. P. STEVENS & CO., INC. INDUSTRIAL GLASS FABRICS DEPARTMENT
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